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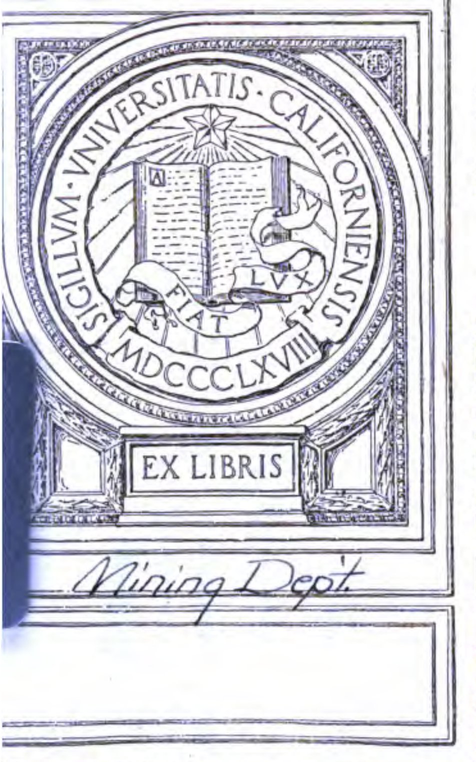
TIN DEPOSITS

OF

THE WORLD.

SYDNEY FAWNS.



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TIN DEPOSITS

OF

THE WORLD,

WITH

A CHAPTER ON TIN SMELTING.

BY

SYDNEY FAWNS, F.G.S.,

Member of the Institution of Mining and Metallurgy; Associate Member of the Institution of Mechanical Engineers; Member of the American Institute of Mining Engineers; Member of the Royal Geological Society of Cornwall.

SECOND EDITION.

THE MINING JOURNAL,

46, QUEEN VICTORIA STREET, E.C.

1907.

TN 470
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MINING DEPT.

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PREFACE.

THE literature of tin mining is at present in a scattered condition. It is the object of the Author to produce a collected account of the tin deposits and methods of tin mining in various parts of the world which will be of some practical value to the Tin Miner and Investor. It is obviously impossible to visit personally all these deposits, and the Author wishes to acknowledge the generous assistance he has received from the Institution of Mining and Metallurgy, Institute of Civil Engineers, American Institute of Mining Engineers, "The Mining Journal," "The Engineering and Mining Journal," "The Mineral Industry," Geological Society of London, Royal Geological Society of Cornwall, Geological Survey of United Kingdom, Geological Survey of United States, Agents-General of Tasmania, New South Wales, Queensland, and Western Australia, Geological Survey of New South Wales and Tasmania, Mr. Donald A. MacAlister, R. Arthur Thomas, Alex. Gilfillan, H. Cutten, J. H. Collins, Henry Louis, N. Samwell, L. Parry, Messrs. Mercer Nicolaus & Co., Lake & Currie, Fraser & Chalmers, and others.

The author wishes to thank the public and the critics for the very favourable reception of the 1st Edition, and the publishers for their kindness and generous assistance. In the second edition the statistics and other matter has been brought as far as possible up to date, and a chapter on Tin Smelting has been added.

SYDNEY FAWNS.

62, *London Wall,*
London, E.C.
April, 1907.

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THE COMMON FORMS OF STANNIFEROUS MINERALS AND EARLY HISTORY OF TIN MINING.

TIN occurs in many forms as :

Native tin.
Stannite (tin pyrites, sulphuret of tin, tin sulphide).
Cassiterite (tin ore, black tin, tin oxide).
Franckeite Cylindrite.
Caufieldite Teallite.
Stanniferous Argyrodite.
Stokesite.

Native tin occurs in Bohemia, Bolivia, New South Wales, and Northern Nigeria; in Banca and Selangor small isolated specimens have been found.

NEW SOUTH WALES, ABERFOIL RIVER.—Native tin in New South Wales was first discovered in the washings from Aberfoil River about 15 miles from the town of Oban, N.S.W. Native tin exists in the form of irregular grains or aggregations of such grains; they are distinctly crystalline from 0·1 to rarely over 1 mm. in size. When magnified 60 diameters they appear to be of an uneven surface, showing places which are too indistinct for determining their form; they are greyish white and of metallic lustre. It was impossible to select enough of the purest grains to make a quantitative analysis, or to determine their specific gravity. A portion treated with hydrochloric acid dissolved readily with disengagement of hydrogen, leaving fine scales of iridosmine behind; not a trace of any other metal but tin could be found in the solution.*

NORTHERN NIGERIA.—By far the most important discovery of native tin has been made in the alluvial wash on the banks of the Kogin River in the Badiko of the province of Banchi in Northern Nigeria, the amount obtained being very large in comparison to any other deposits of native tin. It is found in irregular grains, varying in size from 0·1 mm. to about 3 mm.; it is ductile, and when dissolved the solution contained not a trace of any other mineral. There is apparently no possibility of its having come from any native smelting furnace near. This deposit has never been worked by natives, and the nearest native

* A. Liversidge, "Minerals of New South Wales," p. 77.

smelting furnace is situated over 80 miles away. It is impossible as yet to make definite statements as to its probable origin.

STANNITE (tin pyrites, sulphuret of tin, or tin sulphide).—Commonly massive or in grains. Colour, steel-grey to iron-black; blackish streak. Brittle. Hardness, 4; specific gravity, 4·3 to 4·6; composition: sulphur, 30; tin, 27; copper, 30; iron, 13 to 100.

It is found at Zeehan, Mount Bischoff and other places in Tasmania; also at Dolcoath and other mines in Cornwall; Potosi and Tatasi, Bolivia; and in New South Wales. Stannite has a bronze-like appearance and is frequently called bell metal ore in Cornwall. Being generally associated with copper, it is nearly always sold as a copper ore, the tin being disregarded.

* CRYSTALLIZED STANNITE (Bolivia).—Colour, iron black, with bright metallic to sub-adamantine lustre, somewhat resembling black blende mineral; is opaque streak, black and dull. Hardness, 3½. Fracture, sub-conchoidal. Specific gravity, 4 to 4·5. Chemical composition:—

	I.	II.
Sn.	25·52	24·90
Fe.	10·95	10·90
Cu.	28·58	28·54
Sb.	3·54	3·88
Pb.	2·02	2·09
Ag.	·94	·82

Crystallized stannite has a remarkable similarity to copper pyrites; they are both scalenohedral-tretragonal.

† CASSITERITE (tin ore, black tin, or tin oxide).—Crystallizes in the tetragonal system. The crystals occur in squares, prisms and octahedrons, often in twins. The cleavage is indistinct. It also occurs in a massive form and as grains. It varies in colour from brown-black to yellow. The crystals have high admantine lustre. The streak pale grey to brownish. Hardness, 6 to 7. Specific gravity of the light coloured, 6·4 to 6·85; of the black, 6·8 to 7·02.

Mr. J. H. Collins in his work on tin stones and tin capels, published in 1888, writes as follows;—

There are three distinct modifications of cassiterite.

(*a*) Crystallized (diamond tin, separable tin, rosin tin).
(*b*) Fibrous and radiated (wood tin, toad's eye tin, shoot tin).
(*c*) Pseudomorphous (after felspar, quartz, schorl).

‡ The crystallization of cassiterite was worked out long ago

---

* Jour. Min. Soc., Vol. XIII., p. 54.

† Cassiterite is an original lode mineral; it is insoluble, and consequently is not acted on by the meteoric waters affecting the other minerals of the lodes. The concentration is mechanical and solely the result of the washing away of the sulphides with which it is associated.

‡ Trans. Geo. Soc., Vol. 2.

by Wm. Phillips, who calls attention to the fact that certain combinations of forms are characteristic of certain deposits.

* The crystallization of cassiterite has been also written on by F. Becke, 1877. Crystallized cassiterite is always more or less transparent; it is occasionally nearly colourless, but generally exhibits various shades of brown from brownish-yellow to nearly black. Under the microscope in thin sections it always exhibits a peculiar granular appearance, somewhat like that observable in olivine. The purest crystals are dark with polarized light and crossed prisms, but generally even well-formed crystals exhibit bright sparkling granules due to minute particulars of entangled quartz.† Cassiterite is distinctly dichroic, but usually slightly so.

WOOD TIN.—This is so called because of the resemblance of its fibrous radiated structure to that of exogenous wood; it has been found in both alluvial and lode deposits.‡

At the Garth Mine, two miles west of Penzance, about 1827, wood tin in botryoidal masses and toad's eye tin occurred in great quantity, together with ordinary crystallized tin stone, quartz, felspar, chlorite, and carbonate of iron.§

Wood tin is so nearly opaque and so brittle that it is difficult to get a thin section for microscopic examination; other forms of wood tin are known as "toad's eye" tin, "pea tin" and "shot tin." Pseudomorphous crystals of cassiterite occur after felspar. The silicate of tin described by Mr. Garby is perhaps a pseudomorph after quartz.

Cassiterite is usually associated with granitic rocks, porphyries, gneiss, greisen and metamorphic rocks. In Mexico it occurs in rhyolite and rhyolite-tuff, in Malay Peninsula and Japan in limestone, in Greenland has been found associated with cryolite. The minerals generally associated with tin ore are quartz, muscovite, mica, tourmaline, fluorspar apatite, topaz, beryl, wolfram, molybdenite, mispickel, garnet, biotite, iron oxide, chlorite, felspar, iron pyrites and talc.||

¶FRANCKEITE, a sulphur salt of tin, lead and antimony found at Poopó Oruro Department, Bolivia. Occurs massive with imperfect radiated and foliated structure. Cleavage perfect in one direction; somewhat malleable. Hardness, 2·75. Specific gravity, 5·5; metallic lustre, colour, blackish grey to opaque black; having an average composition of:—

$$\text{I.—}Pb_5,\ Sn_2,\ Sb_2,\ S_2;$$
$$\text{II.—}2\,PbSnS_2,\ Pb_3,\ Sb_2,\ S_6.$$

* Min. Mitt. 1877, p. 244.

† Analyses of crystals of cassiterite almost invariably reveal the presence of small proportions of silica.

‡ Trans. Royal Geo. Soc., Cornwall, Vol. 1, p. 237.

§ Carne, Trans. Roy. Soc. Corn., Vol. IV., p. 99-100.

|| As the terms Cassiterite, Tin oxide, Tin ore and Black Tin are synonymous they are often used by the authors quoted as interchangeable terms.

¶ A. W. Stelzner, Jour. Min. Soc., Vol. II., p. 114 (1893).

Analysis made by C. Winkler as follows :—

S.	21·04
Sb.	10·51
Sn.	12·34
Pb.	50·57
Fe.	2·48
Zn.	1·22
Gangue	·71
	98·87

CYLINDRITE.—A sulphur salt of lead, tin, and antimony from Poopó Oruro Department, and Chocaya Potosi Department, Bolivia. Massive forming, separating under pressure into distinct sheets or folia. It is difficult to pulverize, like graphite. Hardness, 2·5 to 3. Specific gravity, 5·42 ; metallic lustre ; colour, blackish lead-grey, streak, black. Analysis : Sn., 26·37 ; S., 24·50 ; Sb., 8·73 ; Pb., 35·41 ; Ag., ·62 ; Fe., 3·0.

* TEÁLLITE (sulpho-stannite).—Colour, grey-black, metallic lustre. Soils paper like graphite ; occurs in flexible folia ; nearly square outline ; perfect basal clevage. Hardness, 1 to 2 ; specific gravity, 6·36. Orthorrhombic ; chemical composition, $PbSn_2^1$.

† CAUFIELDITE (replaces the germanium).—The mineral occurs in octahedro modified by dodecahedral planes ; brilliant metallic lustre ; colour, black. Hardness, 2·50 to 3. Specific gravity, 6·27. Composition : Sn., 6·94 ; Ge., 1·82 ; S., 16·22 ; Ag., 74·10 ; Zn. and Fe., ·21.

‡ STANNIFEROUS ARGYRODITE (Aullagas, Bolivia).—Crystallizes in simple octahedral crystals, usually with narrow dodecahedral planes ; opaque, with dull iron-black colour streak black and shining. Fracture is even, somewhat brittle. Specific gravity, 6·19. An analysis gave the following result :—

Ag.	74·20
Ge.	4·99
Sn.	3·36
S.	16·45
Fe.	·06
	99·68

§ STOKESITE (silicate of tin).—Crystallographic characters : prismatic (bipyramidal) ; physical characters : cleavage perfect, conchoidal

* A. Frenzel, Jour. Min. Soc., Vol. 2, p. 125 (1893).
† T. Prior, Jour. Min. Soc., Vol. XIV.
‡ Jour. Min. Soc., Vol. XII.
§ Jour. Min. Soc., Vol. XIV.

fracture, brittle. Hardness, ·6. Specific gravity, 3·185 at 2·96. Transparent; colourless; streak, white. Analysis :—

	I.		II.
SiO_2 - -	39·4	-	42·65
SnO_2 - -	33·3	-	35·55
CuO - -	13·4	-	13·27
H_2O - -	8·55	-	8·53
Fe_7O_3 - -	·7	-	—
Na_2O - -	1·3	-	—
Loss - -	3·35	-	—
	100·00		100·00

METALLIC TIN is dimorphous, crystallizing in the forms of the tetragonal and rhombic systems.* A bar of tin when bent emits a characteristic "cry," which is caused by the individual crystals grinding against one another on bending.

† The specific gravity of cast tin is 7·291, of rolled tin 7·299, of electrically deposited tin from 7·143 to 7·178.

Tin is usually contaminated by iron, arsenic, antimony, lead, copper, bismuth, tungsten, molybdenum and stannous oxide.

Tin is used in castings and for coating other metals, especially iron and copper, also extensively employed as tinfoil.

‡ Tin dioxide obtained by a chemical process is employed on account of its hardness in making a paste (putty of tin) for polishing hard stones, sharpening fine cutting instruments, and in preparation of enamels.

The chlorides are used in the precipitation of colour used in dying and calico printing. The bisulphide has a golden lustre and is used for ornamental painting, paper-hanging and other purposes, under name of bronze powder.

§ Tin occupies, in many respects, a unique position amongst the various metals used in the arts, due not only to its specific properties, but to an even greater extent to its mode of distribution and occurrence. In the first place, it is the rarest of the common metals of commerce, and is produced in markedly smaller quantities. Unlike most of these metals, it is distributed sparingly throughout the world, occurring in workable amounts at but few localities; where it does occur, however, it is generally, but not invariably, found in very important quantities. Again, tin is the only common metal, except iron, the only true ore of which consists of an oxide of the metal. All the other metals appear to have been deposited originally as sulphides, their existence in the oxidised state being due to the secondary action of atmospheric agencies upon these sulphides. Hence the other metals are found as oxides near

* V. Foullon, Jahrb. der k. k. geolog. Reichsanstalt 1884, p. 367.
† Schnabel and Louis, "Handbook of Metallurgy," Vol. 11, p. 375.
‡ Dana, "Manual of Mineralogy and Petrography."
§ "The Production of Tin," Louis, published by *The Mining Journal.*

the outcrops only of their deposits, but as sulphides in depths, whilst tin appears as an oxide wherever it has hitherto been found, even in the deepest mines in which it has been met with, and at depths where all other metals are known only as sulphides. It goes without saying that sulphides present far greater difficulties than do oxides as regards metallurgical treatment; the former have usually to undergo a series of more or less complex operations before they can be made to yield up their metallic contents, whilst the latter need nothing more than a simple reduction in an elementary form of furnace. Again, the sulphides of the other ordinary metals, when exposed to atmospheric agencies, form more or less soluble compounds; oxide of tin is notable for its great chemical indifference and for its insolubility in those re-agents that dissolve most other metallic compounds. Hence the degradation of a mineral deposit containing any of the other metals is apt to be accompanied by the removal in a state of solution of those other metals. In the case of tin it will only lead to a concentration and purification of the oxide. This is why oxide of tin (the tinstone or black tin of the miner and cassiterite of the mineralogist) is found to so large an extent in alluvial gravels, a mode of occurrence that it shares almost exclusively amongst metallic minerals with those other chemically indifferent substances, gold and platinum. When a mineral occurs in alluvial deposits, it is far more easily got than when it has to be extracted by a series of laborious operations from hard veins that extend vertically to great depths, and which require considerable mining skill and advanced engineering appliances for their exploitation.

Early History of Tin Mining.

* Tin has been known from remote antiquity, and as early as the 18th dynasty in Egypt bronzes containing 10 per cent. of tin were used for tools and other purposes.

The alloy of copper and tin was much harder than copper, and was consequently much used for making swords, spears, and hatchets. These weapons were not forged, as at the present time, but were cast in moulds and then hardened by grinding on stones.†

The components of the alloy varied in their proportions, as the following analyses show :—

	Copper per cent.	Tin per cent.
An ancient sword	89	11
" " "	85	15
An ancient weapon like a cutlass	90	10‡
A coin of Alexander the Great, 335 B.C.	86·72	13·14

* A. Cooper Key, "Ancient Mining," Trans. Inst. of Min. and Met., April 1896.
† "Ure's Dictionary of Arts, Manufactures, and Mines."
‡ Hawkins, "Observations on Tin Trade of Ancients in Cornwall."

	Copper per cent.	Tin per cent.
A coin of Philippus V., 200 B.C.	85·15	11·10
„ „ Athens	88·41	9·95
„ „ Ptolemy IX., 70 B.C.	84·21	15·59
„ „ Pompey, 53 B.C.	74·11	8·56
„ „ Atilia family, 45 B.C.	68·72	4·77
„ „ Augustus and Agrippa, 30 B.C.	78·58	12·91

(The proportions of the other ingredients are omitted.)*

Nearly all the tin used by the ancients was procured by the Phœnicians from the Cassiterides. A great deal of speculation has been indulged in as to their position, and many authors have been at great pains to endeavour to prove that they were situated to the east of Phœnicia in the neighbourhood of India. The great weight of evidence and the testimony of the most learned archæologists is, however, that they corresponded to the Scilly Isles and Channel Islands, and, more particularly, Cornwall, which was in those days supposed to be separated from the mainland.†

Two derivations have been suggested for this word Cassiterides but, they may be independent or in reality one. "Kassiteros" is the Greek word for tin; but, possibly, this is the equivalent of the Hebrew word "katseh"—finis, meaning the extremity of the earth, which the coasts of Britain would have been to the ancients.

The commencement of the Phœnician working in these islands has been assigned as about twelve centuries B.C. Diodorus Siculus, writing just before the Christian era, and repeating what had been told by more ancient chroniclers, giving an account of the work of the inhabitants of the west of Britain, says,‡ "They prepare the tin, very carefully working the earth which produces it; the ground is rocky, but has in it earthy veins, the produce of which is brought down and melted, and purified. Then, when they have cast it into the form of cubes, they carry it to a certain island called Iktis. During the recess of the tide the intervening space is left dry, and they carry over abundance of tin to this place in their carts."

The Truro Museum contains a bronze casting of a bull about 2 inches in height which was found in Cornwall with many distinguishing features of Assyrian bronzes. Moreover, a similar figure has been discovered in Babylon.§

In 1849 Mr. Richard Edmonds discovered near Marazion a vessel resting on charcoal ashes, charcoal and slag being also associated. This was conjectured to be the remains of an ancient bronze furnace, but Professor Hunt is of opinion that it was only used for domestic

* "Ure's Dictionary of Arts, Manufactures, and Mines."
† George Smith, "The Cassiterides."
‡ This translation is from Hunt's "British Mining."
§ Hunt, "British Mining."

purposes, on account of the "action of the molten tin upon a vessel containing copper in its composition, which would be disastrous to the vessel."*

The tin worked was probably of detrital origin.* The Phœnicians jealously endeavoured to keep the tin trade to themselves, and for some centuries they maintained the monopoly.

It seems uncertain how long the Phœnicians were masters of the situation, but it was probably during a period of about 300 to 400 years. At the end of this time the whereabouts of the Tin Islands were at last discovered by the other nations, and the Romans, Greeks, and Gauls then came in to work the mines.

† It is certain that the first tin worked for many ages was derived exclusively from alluvium. It is impossible to say when lode tin was first discovered and worked.

The earliest German writers on these matters, Agricola and Ercker, in the 16th century, describe the crushing and washing of tin-bearing rocks as though this were a quite familiar operation, long known and then already in a relatively high state of development.

During, at any rate, the 17th and 18th centuries, Cornwall seems to have been the main source of the world's tin supply, its development having been steadily progressive for many centuries. The average annual production during—

	Tons.
The 13th century is said to have been about -	300
,, 14th to 16th ,, ,, ,, -	500
,, 17th ,, ,, ,, -	1,200
,, 18th ,, ,, ,, -	2,600

* Hunt, "British Mining."
† "The Production of Tin," Louis, *The Mining Journal.*

CHAPTER II.

DESCRIPTION OF TIN DEPOSITS.

THE deposits in which tin occurs in economic form may be divided into three divisions : (*a*) Fissure Deposits, (*b*) Masses, (*c*) Alluvial Deposits. There are several sub-divisions under these headings, such as Lodes, Dykes, Contact Deposits, Stockworks, Carbonas, and Impregnations.

(*a*) *Fissure Deposits, Lodes.*

The term "lode" as used by the practical miner includes the whole of the workable band of mineralized country by the sides of the fissure as well as the actual fissure filling. The great majority of this class of ore deposits are of a later origin than the surrounding rocks.

The term ore is limited to metalliferous minerals of commercial value still associated with the vein-stone matrix in which they occur.

The contents of lodes result from one or more of the following actions :—

(1) Infilling of a fissure by minerals derived from a distant source.

(2) Alteration and impregnation of the country rock in the vicinity of a fissure by minerals derived from the fissure.

(3) Alteration and impregnation of a friction breccia (modification of Nos. 1 and 2).

Many lodes are planes of faulting, and in consequence of comminution of the walls during movement of some sort, a great many of them come under Class (3).

If a mineralized fissure in the lode area has all the peculiarities of one of the ordinary lodes, such as direction of strike and the character of the vein-stone, this vein is called a lode by the miners, whether it contains payable ore or not.

Many lodes have been built up more or less intermittently by the deposition from solution of a number of substances, some of which were more or less chemically active than others, the result being that the lode

displays a variety of structures. Thus the simplest structure which a lode can have is that which constantly figured in text-books—"the Comby structure." There the lode is built up in layers parallel to the walls of the lode, such layer representing a period of deposition and possibly indicating repeated widening of the fissure, a feature characteristic of tin lodes is the alteration of the country rock immediately adjoining the fissure. This change is the result of metasomatism—that is, the modification of the rock effected by the addition or taking away of material. In many cases the rock adjoining the lodes is worth breaking down for the cassiterite it contains.

Fissure lodes are supposed to have originated in the fissures or dislocations which have been produced by various movements of the earth's crust.* A fissure lode or its branches may at times coincide with the dip of the strata, or the cleavage, but are subject to considerable variations in underlie; in some districts the average inclination of tin lodes has been accurately determined, as for instance in Cornwall, where the average inclination has been given by Mr. Henwood at 60°.

In all the various forms that tin deposits *in situ* assume, fissure lodes or veins are the most important; they are the source of many valuable ore deposits, and from their regularity and persistency, make systematic and continuous working a profitable investment.

Lodes or veins occasionally meet without intersection or displacement; under this condition it is generally assumed that the lodes are of the same geological age, and were contemporaneously filled with veinstone or ore.

In 1839 De la Beche pointed out that it is possible to fall into error if we assume one lode to be older than another simply because the one lode appears to be heaved by the other. The information concerning the precise phenomena of the intersection of tin lodes is, however, extremely meagre, and a very careful consideration of the facts governing each case is necessary before any definite statement could be made regarding the relative ages of the lodes.

Frequently Lodes are produced by the dislocation of the walls of fissures, so that as a rule the walls have slid over one another, leaving open and closed parts.*

The Dolcoath main lode in Cornwall is an excellent example of a fissure deposit, and has been worked continuously for over a century. It possesses some instructive and interesting geological features, and several of the most important of these are given below.

This lode passes from killas to granite without interruption. On the surface of the lode a fine "gozzan" extended down for many fathoms, which in places contained a good deal of tin; the country rock changes noticeably with the lode matter. The killas is fairly soft near the surface, generally becoming harder as it approaches the

* Josiah Thomas (Jour. Roy. Inst., Corn., 1868, Vol. III.) observed that the widest part of the lode occurs principally where there is an abrupt change in the strike, and constitutes a noticeable feature in the tin-bearing lodes of Cornwall.

granite, but it is always soft near the rich parts of the lode. Where the granite is very hard the lode remains poorer in tin. The curious alternations of killas and granite through which this great lode cuts in the upper levels has been noticed by many writers.

The exact depth at which lodes cease to be payable varies considerably with the country rock, and the district in which they are found. In Cornwall, it may be stated, tin lodes have remained payable down to over 3,000 feet. Dolcoath is one of the examples of tin ore remaining payable at great depths.

Tin lodes differ considerably in character. In no place have they been so extensively worked and carefully examined as in Cornwall, but the author is much impressed with the many features possessed in common by the lodes examined by him in Tasmania, New South Wales, and the Malay Peninsula, with those of Cornwall.

It is impossible here to discuss at length the origin of tin deposits *in situ*, but a few main facts by recent observers may be cited.

In reference to Cornwall Dr. J. S. Flett of the Gov. Geo. Survey in 1903 writes as follows on "The Stanniferous Veins of Cornwall" :—

"These modifications of granite, elvan, and killas are the usual accompaniments of the stanniferous veins, with which they have undoubtedly a close genetic connection. In the veinstones quartz, tourmaline, and a rather strongly polarising chlorite, are the commonest minerals. Pyrites, arsenopyrite, chalcopyrite, fluorspar, and apatite are rarely absent. The rocks which are worked as tin ores vary greatly in character and in origin. Altered granites, killas, and true vein deposits may all contain sufficient tinstone to enable them to be worked for the metal. The true quartz lodes with cassiterite are very interesting, as it is possible in some cases to show that they have a complex history, as was pointed out by Mr. Collins.* The successive stages of their formation can be made out with the help of the microscope, and it can be shown that the fissures have been opened, filled with quartzose vein stuff, which was then crushed up by movement of the walls, and that these processes have been repeated three or four times in some of the great lodes. Fragments of the first deposit lie scattered in a matrix of the second, which in turn may be broken and cemented together by a third infiltration.

"The tin veins are undoubtedly later than the granites and the elvans, yet they show perfect cataclastic structures, which are singularly rare in the igneous rocks. The later movements of adjustment seem to have taken advantage of the existence of the fissures, and instead of interstitial granulitisation taking place in the intrusive masses, these narrow veins of quartz, perhaps not entirely consolidated at the time, have yielded to the stresses, and in so doing have had their minerals shattered and ground down. This explains the occasional occurrence of gneissic or granulitic types of elvan and

* "Min. Mag.," Vol. IV., p. 20.

granite in Cornwall—a fact which has been brought to my notice by Mr. J. B. Hill. Where the main granites are entirely massive, some of the dykes or smaller sills are intensely sheared. Yet there is reason to believe that they are later than the granite itself in some cases."

In deciding the age of a lode it must not be assumed that mineralization of the fissure commenced immediately after its formation, movements operating for the production of a certain series of fissures were undoubtedly followed by a period of mineralization which may have occurred simultaneously or may have extended over very lengthy periods of time.

Cross veins are wider in granite than in slate, and at great depths than near the surface.

The mean width of cross-veins in granite is 4·9 feet.
" " " slate is 3·5 "
" " at less than 600 feet deep is 4 "
" " at more " " 4·4 "

These veins alter considerably with the nature of the country through which they run.

Out of 272 lodes recorded by Henwood as being divided by cross-veins in different parts of Cornwall—

57 or 0·20	of the whole number were	intersected but not heaved.
135 or 0·30	" " "	heaved towards the right hand.
80 or 0·30	" " "	heaved towards the left hand.
181 or 0·67	" " "	heaved towards the greater angle.
34 or 0·13	" " "	heaved towards the smaller angle.

* The figures given by Mr. Henwood would probably differ considerably if they were to include the workable portions of the lodes and veins.

Dykes of quartz porphyry, known in Cornwall as elvan courses, often carry tin oxide. These elvans are intimately associated geographically with the lodes; that is to say, they occur in the principal mineral areas, and like the lodes, occupy fissures which traverse alike both the granite and killas. They may be regarded as an indication of the presence of granite, since they are supposed to be derived from the same magma; the tin lodes themselves were formed during the later stages of the consolidation of the granite, and generally they are of later age than the elvans. They are generally large; their bearing is tolerably

* J. H. Collins, "Origin and Development of Ore Deposits."

analogous to that of the principal lodes in each district. Since the one operation followed so closely on the other, it is not surprising to find that many of the ore bodies are actually found in or alongside of the elvans.

Some very good examples of this class of tin deposit occur in the St. Austell and other districts in Cornwall, and also on the north-east coast of Tasmania, where these stanniferous dykes or elvans have been extensively worked by the Anchor Tin Mine, Limited, and others.

Mining operations have revealed the presence of a greater number of elvans both in the granite and killas than can be found on the surface. These elvans are often split up at a depth, and the general mode of occurrence of the elvans suggests the infilling of fault fissures by igneous matter.

The chief characteristic of these dykes or elvans in Tasmania is their size, and, although the stanniferous value of these deposits is low, still, with modern appliances and worked on a large scale, they possess considerable economic importance.

The following figures illustrate some of the varied forms in which tin lodes and dykes occur in Cornwall.

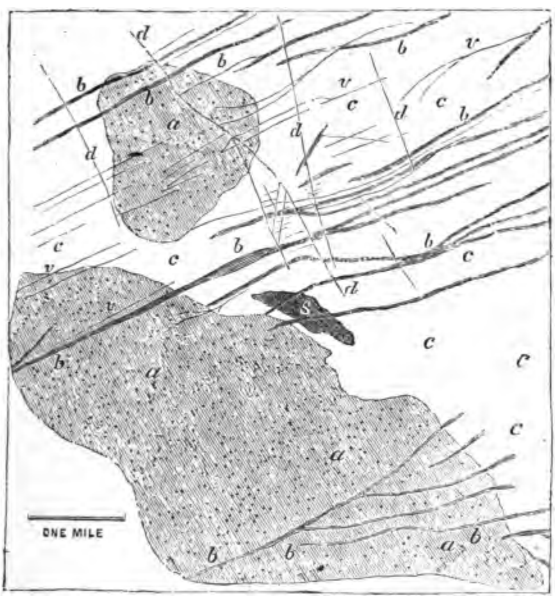

FIG. 1.—MAP OF PART OF THE MINING DISTRICT OF GWENNAP, CORNWALL (*B.*).

a a, Granite; *c c*, Schistose rocks; *b b*, Elvan dykes; *s*, "Greenstone," *v v*, *d d*, two interesting series of mineral veins. (Archibald Geikie.)

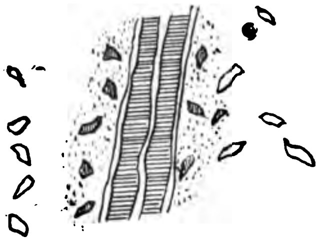

FIG. 2.—Tin vein in Cornwall, with pseudomorphs of cassiterite after feldspar in the granite country rock. (C. Le Neve Foster.)

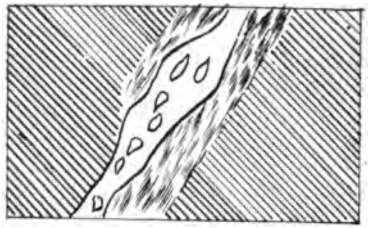

FIG. 3.—Tin vein in Cornwall, showing "capel" or altered "killas" country rock. (C. Le Neve Foster.)

Contact Deposits are stanniferous lodes or veins which occur at the planes of contact of dissimilar rocks. This class of deposit is parallel to the stratification when it occurs between stratified rocks, but is often found in irregular or rounded masses of a lenticular shape in the spaces formed at the junction of two different rocks. Contact Deposits generally occur at the junction of eruptive and stratified rocks.

A very good example of this class of deposit occurs on the Bundi Tin Mine in Tringganu on the east side of the Malay Peninsula.

The foot wall of this stanniferous ore-body is granite, while the hanging wall consists of schists and slates, as will be seen from the accompanying sketch.

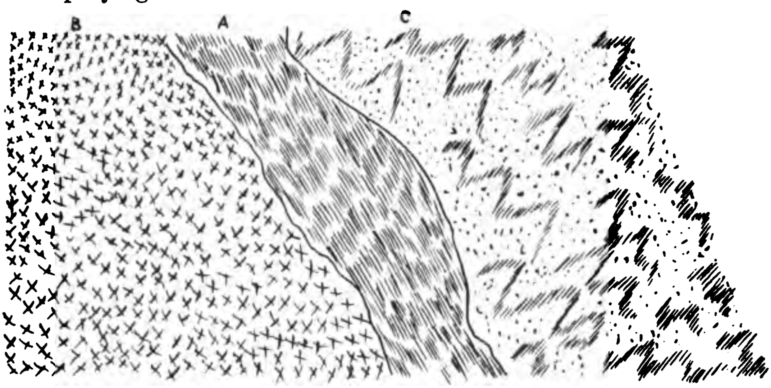

FIG. 4.—*A*. Lode. *B*. Granite. *C*. Schists and Slates.

(*b*) *Masses, Stockworks.*—In many tin fields bands or belts of "Country rock" are found, which are traversed by numerous small veins thinly lined or sprinkled throughout with small spots of metalliferous substances, the whole mass being of considerable value. An ore mass of this nature is called by the Germans a "stock," and a working upon such a mass a "stockwerk," or, as the term has been adopted in England, "a stockwork."

The origin of these stockworks is not always clear, but in the majority of cases they are formed by the impregnation of a number of joints,

cracks, or mere lines of rifting situated closely together. The country rock in the vicinity of these joints is generally altered to greisen and other varieties of pneumatolytically altered rocks to an extent entirely obliterating the original character of the rock. The resulting mass may have a homogenous appearance or may be banded in manner indicating their origin.

Since the individual strings or nests of minerals are usually insignificant, it is necessary in stockwork mining to remove the whole mass of impregnated rock, or at any rate to treat the greater portion, in order to concentrate and separate its valuable contents.

As the ores so distributed form a very small proportion of the rest of the rock (generally about 10 tons of ore to the ton) a combination of favourable circumstances is necessary to work them at a profit, and very few will pay to mine except as open quarries.

Tin stockworks in Cornwall have been worked in ordinary "killas," as also in granite and modifications, greisen, schorlomite and felspar porphyry (elvans).

In Tasmania stockworks are mined extensively in the Blue Tier district, where they occur in a quartz porphyry. (See Chap. IX.)

In the "Great Wheal Fortune" mine, Cornwall, a tin stockwork in killas associated with a lode has been worked. The principal excavation runs S.W. and is about 400 feet long and 50 feet wide and 60 feet deep. The average produce of the stuff stamped and treated is about 12 lbs. of tin to the ton. Tin stockworks in granite have been worked which were unconnected with lodes, the granite in which the disseminated tin ore occurs being almost invariably altered into greisen, schorlomite, or zwitter.

Very large stockworks occur in the tin fields of Altenberg, Saxony. These have been minutely described by Cotta, Dalmer and others.

. According to Dr. Karl Dalmer* a belt of eruptive rocks breaks through the Archæan sedimentary formations of the Erzgebirge in a north-west line, along which are a series of fissures and important faults. These eruptives may be classified as (*a*) quartz porphyry, (*b*) granite-porphyry (younger than the former), and (*c*) a series of intrusive cones of granite (the most recent of the series). The tin deposits are closely connected with the last named. They take the form of "impregnation fissures," that is, fissures in the immediate neighbourhood of which, whether filled or empty, the country rock is changed into a greisen impregnated with tin-stones, the width of the zone so altered varying from a few inches to some yards. These impregnation fissures are closely associated with the granite masses and the rocks in contact with them. In the granite cones they are generally confined to the boundaries thereof with the older porphyry, so that an outer ore-bearing capping may be distinguished from the inner unaltered poor or barren rock which succeeds it in depth. This phenomenon is well

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* "Der Alternerz-Graupener Zimmerzlagerstatten District," Zeitsch. f. prakt. Geol. 1894, p. 313.

marked at Altenberg, where a granite cone breaks through the granite porphyry. The upper part of this cone is so completely traversed in every direction by a close network of impregnation fissures that the entire mass, except for some residual portions, has been altered to a stockwork (Zwitter-gestein) of ore bearing greisen, which extends to a depth of some 230 metres below the summit of the eruptive cone, at which point the undecomposed granite, containing but a few narrow belts of impregnations, makes its appearance.

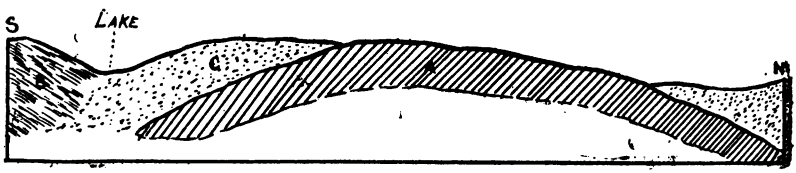


FIG. 5.—VERTICAL SECTION THROUGH TIN STOCKWORK AT ZINNWALD, AFTER DALMER.

A. Granite shaded portion shows limit of tin-bearing rock. *B.* Quartz Porphyry. *C.* Zone of impregnation.

* Carbonas are a somewhat similar class of deposit as stockworks. They may occur as either isolated ore bodies, or associated with a deposit of a well-defined character. W. J. Henwood, in "Trans. Royal Geol. Society of Cornwall," quotes the example of the St. Ives Consolidated Mine, where the carbona joined the Standard lode at a depth of 468 feet; at this point it was only 5 inches square, but widened out to 60 feet, and was worked for 720 feet in length. This deposit was enclosed in both sides by granite, and consisted of quartz, felspar, schorl and oxide of tin, the chief characteristic being the gradual transition from granite to the carbona.

A section of this deposit, by H. C. Salmon, taken from "The Mining and Smelting Magazine." (See Fig. 6.)

Impregnations occur as very irregular tin deposits, in conjunction with lodes and generally associated with granite. They have no definite bedding planes, and are termed by the miner lode matter, and it seems better (except for purpose of classification) for the geologist to give way and suit his definition to the wants of the miner, as it is too much to expect the miner to give up a term consecrated by universal usage, because geologists have in the past made the mistake of supposing all lodes to have been formed on the same plan.

The Figs. 7 and 8 give an idea of a common form of a Zone of Impregnation.

* Collins, "Origin and Development of Ore Deposits."

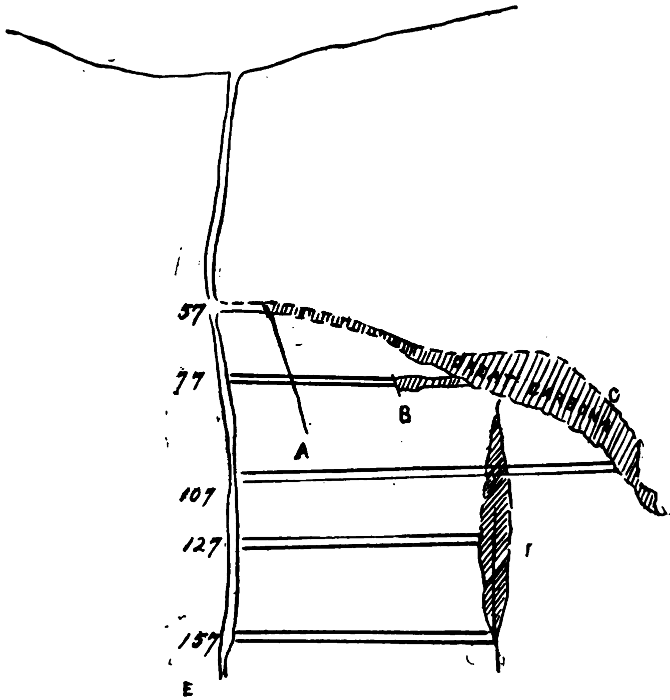


FIG. 6.—CARBONAS AT ST. IVES CONSOLS.
A. Williams' lode. *B*. Kemp's lode. *C*. Great Carbona. *D*. Daniels' lode. *E*. Standard lode.

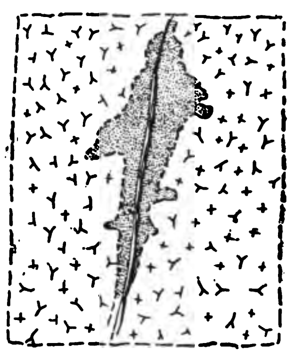


FIG. 7.—Impregnation of tin ore at East Wheal Lovell, Cornwall. (C. Le Neve Foster.)

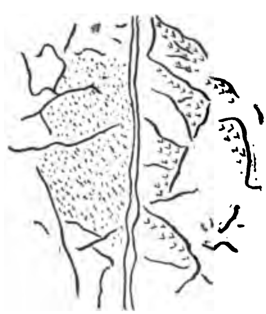


FIG. 8.—Impregnation of tin ore at East Wheal Lovell, Cornwall. (C. Le Neve Foster.)

(*c*) *Alluvial Tin Ore Deposits* have been derived from the disintegration and denudation of older mineral deposits. In most cases the material has been carried and re-deposited by the action of water, often at considerable distances from their source. Some of these alluvial deposits are of great geological age, the alluvial tin ore deposit near Avoca, Tasmania, being of post-carboniferous age (*see* Chapter II.), but the majority of such deposits belong to the late Tertiary periods.

The general law which seems to govern these deposits would appear to be that the relation of the depth of the overburden to the depth of wash is in the ratio of about one to four.

* The following are five sections of alluvial tin leads from the Kuita district, Malay Peninsula, which average about 4 feet of overburden to 1 foot of wash with ore :—

I.	ft.	in.
Vegetable mould	1	3
Loam	1	0
Sand	4	0
Bluish clay	3	6
Darkish clay	3	9
Stratum with ore	6	0
	19	6

II.	ft.	in.
Mould soil	3	0
Clay varying dark yellow to pale grey	12	0
Light gravelly drift	3	0
Stratum with ore	6	0
	24	0

III.	ft.	in.
Mould soil	4	0
Sand varying from white to brown	4	0
Dark grey sand	6	0
Stratum with ore	4	0
	18	0

IV.	ft.	in.
Red loam	4	0
Sand drift	8	9
Whitish grey clay	9	3
Stratum of ore	6	0
	28	0

V	ft.	in.
Red earthy loam	5	0
Whitish grey clay	3	6
Drift sand	8	6
Stratum of ore	8	0
	25	0

These will average about 4 to 1.

* P. Doyle, Vol. XXXV., "Jour. Geo. Society."

Mr. J. H. Collins gives the following definition of alluvial ore deposits :—" All clastic rocks, such as conglomerates and sandstones, and even some clays, may be regarded as detrital deposits, whatever their geological age. But the term is by custom restricted to the but little consolidated sands and gravels of the later geological periods. Such beds are found to contain distributed particles of ore-matter, apparently derived from pre-existing rocks ; and when these occur in workable quantities, or nearly so, the beds themselves may be classed as detrital ore deposits."

There is very little alluvial tin ore remaining in Cornwall. Geologically there are two varieties :—

(*a*) * As a constituent of river gravel or sea beaches now in process of formation the tin ore referred to is generally in very small particles, often angular and sub-angular.

(*b*) The elevated stanniferous gravels such as those of the "Blue Pool" in Crowan referred to by Mr. Zyack.†

There is distinct evidence that in some instances at least very considerable thicknesses of overburden resting upon the tin gravels have been accumulated within comparatively recent periods.

The actual proportion of tin oxide present in stanniferous gravels is very small, but represents a considerable amount of denudation.

Frequently the deep alluvial deposits occupy the bed of an ancient river flowing through valleys, which have been subsequently filled by the outpouring of volcanic matter. A good example of this is the Deep Lead worked by the "Briseis" and "Brothers Home" Mines in Tasmania, which was undoubtedly at one time the bed of the old Ringarooma River. The overburden has an average thickness of over 100 feet, the present surface being formed by an immense flow of basalt, which is fully 80 feet in thickness in parts. These ancient valleys were eroded at a period when the relative positions of the land and sea were entirely different, as they are often much below the present sea level. As evidence of this, the author would instance the deep alluvial Tin Lead at St. Helen's, on the east coast of Tasmania, where the bottom of the lead is over 100 feet below sea level.

In the Malay Peninsula, at Kampong Ling, tin ore was worked on the sea beach, the sand being washed on the spot in little wooden troughs about 7 feet long by sea water, but the ore won was too poor to pay expenses.

Alluvial tin ore occurs in nearly every part of the Malay Peninsula for a distance of 900 miles, the chief district being Kinta, Perak. The main features of interest in that locality are reproduced in nearly every large area of alluvial tin ore. Much of the alluvium contains the cassiterite in particles and fragments of varying size, sometimes scattered from top to bottom in comparatively uniform quantities, and

* Collins, "Origin and Development of Ore Deposits," p. 184.

† "Trans. Roy. Geo. Soc. Cor." IX., p. 177.

in other cases in layers separated by barren ground, and often richest near the bed-rock. (But in the author's experience it is a common mistake to imagine the richest ore must necessarily be on the bottom.) The overburden varies from 10 to 40 feet, and the best ground occurs immediately at the foot of the mountains. Higher up it is often richer, but of small extent, while further away it is thicker but of lower grade.

The ordinary tin-bearing beds vary from 1 to 30 feet in thickness, though sometimes they reach over 100 feet.

In one instance the tin-bearing formations extend from the surface down to a depth of from 5 to 50 feet, without any barren overburden. In another instance large open pits in the alluvium of the river valley show tin-bearing strata, varying from 2 to 10 feet in thickness, with a barren overburden of 40 feet in thickness. In another instance the overburden is from 30 to 40 feet in thickness, and the tin-bearing ground below has penetrated 140 feet vertically without reaching the bottom. In the mountains near its source the ore is angular and in comparatively large fragments, sometimes from an inch to a foot or more in diameter. Further down the hill it becomes more and more rounded and finer in grain.

At Vegetable Creek, New South Wales, the tin gravels are derived from masses of granite which are penetrated by numerous small tin veins, but no tin-lodes or stockworks have as yet been profitably exploited. The width of the channel deposits of Vegetable Creek vary from 5 to 15 chains or from 330 to 990 feet, the richest portion being from 1 to 5 chains wide. The average thickness of the stanniferous gravels is about 2½ feet, yielding about 20 lbs. to the cubic yard or 0·8 per cent.

The older depositions of alluvial tin ore appear to be mostly of Miocene origin, and undoubtedly very considerable changes have taken place in this class of deposits. To illustrate the important changes that occur in the deeper gravels subsequent to their deposition in silicification, there are in the British Museum,* as well as in the Museum of the Royal Geological Society of Cornwall, fragments of antlers containing tin oxide, which appears to be pseudomorphous after the organic tissues. Many of the fragments are said to have been found in the streamworks of the Pentewan and Carnon valleys. Some of the specimens preserved in the British Museum appear to contain a large quantity of tin. In many parts the original structure seems to have disappeared and to be entirely reproduced as cassiterite.

* Phillips and Louis "A Treatise of Ore Deposits," p. 33.

TYPICAL ALLUVIAL TIN MINE, MALAY PENINSULA.

CHAPTER III.

ALLUVIAL TIN DEPOSITS OF THE MALAY PENINSULA.

THE deposits of alluvial tin ore have in the past history of tin mining, and still continue in the present, to supply by far the greater proportion of all the tin raised in the world. The chief sources of supply are situated in the Malay Peninsula, Banca, and Billiton.

These deposits may be said to extend from about the 12 degrees N. lat. to Banca and Billiton in the south.

The Malay Peninsula is the south-eastern extremity of the continent of Asia, extending from about latitude 14° N., in a southerly and south-easterly direction to about latitude 1° 20′ N., and consisting of a narrow strip of land about 900 miles in length and from less than 50 miles to over 150 miles in width. The northern part of the peninsula belongs to Siam, though the British possessions of Burmah include some of the north-western part. The central and southern part of the peninsula is comprised mostly in the native States of Perak, Pahang, Selangor, Negri Sembilan and Johor, ruled by independent Sultans, but under British protection, and now combined under the name of the Federated Malay States.

* The Federated Malay States at present comprise most of the tin regions worked on the peninsula, and tin deposits occur in greater or less quantities from the State of Johor, in the southern extremity of the peninsula, northward to the limit of the State of Perak on the Siamese border, a distance of some 350 miles. To the north of this limit, in Siam, the tin deposits have not been much explored, and no very prominent mines have been opened as yet. By far the larger part of the tin of the peninsula is mined in the States of Perak and Selangor, while very little has been mined in Johor, and the production of Pahang and Negri Sembilan is small. Perak supplies considerably over half of the tin of the peninsula, and the Kinta District is at present the most important tin locality in that state. In Selangor the

* The Federated Malay States of the Malay Peninsula consist of the four states of Perak, Selangor, Negri Sembilan, and Pahang. They adjoin each other; the three first-named states lie on the western side of the chain of mountains which forms the backbone of the peninsula, while Pahang is situated on the eastern side of the range, extending to the shores of the China Sea. The total area of the four states is estimated at about 27,000 square miles.

most important mining centre is Kuala Lumpur, and the production of this region is second only to that of the Kinta District. Besides the places already mentioned many other smaller tin districts exist, and in fact most all of the numerous small native towns on the west slope of the peninsula are largely dependent on the tin industry.

General Geology of the Malay Tin Regions.—The Malay Peninsula consists of a central axis of rugged mountains with occasional subordinated parallel or diverging axes and isolated peaks. The whole region is covered by a jungle of tropical vegetation so dense that the roads and trails have to be hewn through it with an axe. In the tin regions the main range is composed of granite rocks, occasionally intersected by felspathic and other dykes, while in places are found gneissic and schistose rocks with occasional areas of a white highly crystalline limestone. The granite is mostly of a grey colour, and is composed of quartz, felspar and biotite, or hornblende, or both. Occasionally strata of a fine-grained friable sandstone occur on the lower slopes of the mountains. The granitic rocks and limestone, however, are the formations most commonly seen in the few places where any rocks appear through the soil.

It is in the mountain valleys and the extensive lowland near the coast that the large areas of alluvium are found ; the stanniferous portion varies in thickness from a few inches to 16 feet, and generally in relation to the overburden, which also varies from about 1 foot to 80 feet. There are three distinct forms, which are given below :

1. Surface alluvial.
2. Shallow alluvial.
3. Alluvial deep leads.

(1) *Surface Alluvial.*—Top soil carrying payable tin right down from the grass roots. This class of deposit seldom much exceeds 15 feet in depth, and may be termed "surface alluvial."

(2) *Shallow Alluvial.*—Stanniferous washdirt, usually 10 to 20 feet deep, lying under 15 to 20 feet of overburden. This is the most usual form of deposit met with in Perak, especially in Kinta, and will be referred to as "shallow alluvial." It will sometimes happen that there are two layers of washdirt, known respectively as "karang gantong" (hanging washdirt) and "karang betul" (true washdirt) with 10 to 20 feet of barren soil or gravel intervening, before the "kong" or bed-rock is reached. It is hardly correct, as has been stated by some, to say that this upper layer is generally unprofitable. In Perak, at least, it often happens that it is quite as payable as the lower layer, and occasionally even more so ; indeed, there appears to be no general rule on the subject. This class of deposit is naturally more expensive to work than the "shallow alluvial" previously described, as the overburden has to be stripped before the payable part can be attacked.

(3) *Deep Leads.*—"Deep leads" with 30 to 50 feet of overburden, and occasionally even more. Here, either open cast workings on a

considerably larger scale must be carried out, or shafts sunk, and the deposit worked on a regular system of underground mining. However correct it may have been a few years ago to state that this form of deposit was but little known in the Straits, it can scarcely be said to apply at the present time in view of later developments. Indeed, to-day many of the largest Chinese workings in Perak and Selangor are on "deep leads," and some have been carried as deep as 400 feet.

* *Value of Tin Alluvial.*—To give some idea of how rich some of the Perak tin gravels have been, a list of twelve samples, taken about two years ago by the State Geologist from Chinese mines in the neighbourhood of Taiping, is appended :—

No.	Lb. of black tin per cub. yd.
1	77·375
2	22·793
3	20·220
4	18·719
5	17·899
6	15·864
7	15·327
8	15·044
9	12·894
10	10·299
11	10·179
12	5·455

Average of 11 samples = 14·972 lb. per cub. yd. The first sample, being of quite exceptional richness, is omitted in taking the average. With metallic tin at $32·00 per pikul (at the mean rate of exchange taken) = £59 8*s*. 4*d*. per ton, and assuming the produce to be 70 per cent., the mean value of the 11 samples works out at $2·51 (5*s*. 6½*d*.) per cub. yd. The average value of alluvial throughout the state is nothing like so high as this at the present time ; 2 to 4 katis (2·6 to 5·2 lb.), equivalent on the same basis to 64c. to $1·28 (1*s*. 5*d*. to 2*s*. 10*d*.) per cub. yd., would be a good deal nearer the mark. Perhaps it would not be far out to say that 1 kati (1·3 lb.) of black tin (=32 c., or 8½*d*.) to the cub. yd. about represents the limit of payable washdirt with an average alluvial mine in Perak.

The rise in the price of metallic tin from about £60 per ton in 1897, when Mr. Owen compiled these figures, to the present price of about £190 per ton, causes considerable difference in values.

Thus 1 kati (1·3 lb.) of black tin would now be worth 50 c. (or 1*s*. 4*d*.) to the cubic yard.

This rise naturally widens the area of payable operations, and there are large areas of poor ground which can now be worked at a profit. But the profits of the Chinese mine proprietor, employing much labour, have not increased as rapidly as might be supposed from the fluctuations in

* Owen, F., "Trans. Inst. of Min. and Met.," Vol. VI., 17th Nov. 1897.

tin quotations recently. The cause of this has been in the standardization of the dollar at 2*s.* 4*d.* (56 cents), after fluctuations from neighbourhood of 1*s.* 9*d.* to 1*s.* 11*d.* (42 to 46 cents). Yet the wages of coolies have seen no diminution. Nearly all the expenses incurred by the mine-owners, save the importers of coal and machinery, have advanced proportionately. During the three years, 1902, 1903, and 1904, the average valuation was $80 per picul (133 lbs.), and had the

Fig. 9 Fig. 10 Fig. 11

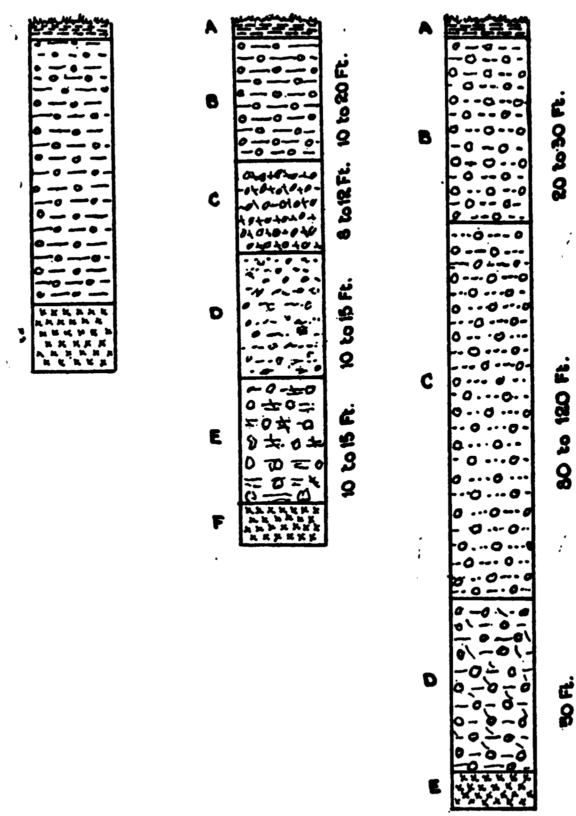


FIG. 9.—SECTION OF SURFACE ALLUVIAL DEPOSIT.

A. Surface. *B.* Sandy and clayey; stanniferous washdirt. *C.* Bed-rock—granite or limestone.

FIG. 10.—SECTION OF SHALLOW ALLUVIAL DEPOSIT.

A. Surface. *B.* Overburden—sandy and clayey. *C.* Stanniferous washdirt (karang gantong) or hanging washdirt. *D.* Barren gravel. *E.* Rich stanniferous washdirt (karang betul or true washdirt) containing crystalline quartz-felspar, etc. *F.* Bed-rock—granite or limestone.

FIG. 11.—SECTION OF ALLUVIAL DEEP-LEAD

A. Overburden—clayey and sandy. *B.* Stanniferous washdirt (25–50 catties of tin per cubic yard). *C.* Stanniferous washdirt (25–70 catties of tin per cubic yard). Slightly mineralized (pyrites).

dollar been 2*s*. 4*d*. (56 cents), would have been equivalent to £160 ($800) per ton.

The three typical sections shown here were prepared for the author by Mr. N. Samwell, who has had considerable experience in working the Malay alluvial deposits.

Fig. 11 is taken through the Ipoh Valley and Perak; no bed-rock was reached at a depth of 200 feet—the bed rock reached in the shallower mines here is Limestone. Some deep leads in Malay have been worked down to 400 feet before reaching bed-rock.

The exact origin of these deposits is still a matter of controversy, but when the geological survey, now in progress, of the Federated Malay States is finished very valuable data will be furnished. In general they have doubtless been derived from the denudation of the granities, and other tin-bearing matrices, some of which are comparable with the stockworks of Saxony, Cornwall, and elsewhere.

This view has received considerable support from the discovery in some deep workings in Kuchai, in Selangor,* of narrow veins of cassiterite traversing a formation consisting of quartz with a little felspar, capped with kaolin, produced by its decomposition *in situ*, and containing much disseminated cassiterite. It is possible that the stanniferous portion of the granite formed a shell on the unaltered central portion; the tin being developed at the junction of the granite with the stratified rocks on its flanks, as in the case of the Erzgebirge in Germany.

The author has had the opportunity of examining large bodies of alluvial wash in close proximity to their known source in the province of Kemaman, in the north-east of the Peninsula, at the Bundi and Sughie Ayam Mines. Large quantities of alluvial tin were recovered from the karang or stanniferous gravels on the eastern side of the lodes in this district; the strike of the lodes being practically north and south in both cases. The topographical features of the country are a continuous slope of the ground towards the east, and a continuous rise of the ground towards the west. In neither case was any payable alluvial found on the western side of the lode; the lodes occurring on the contact of the slate and granite country. The débris showed both boulders of granite and slate. In some of the old alluvial workings at Sughie Ayam a number of both large and small boulders, rich in finely disseminated cassiterite, also of quartz with nodules of cassiterite, have been stacked by the Chinese workers. These boulders show very slight signs of denudation, and closely resemble the lode matrices which are at present being worked a short distance away from where they were found. At a greater distance the wash has been covered to a depth of some 10 to 20 feet with overburden, consisting mostly of clay with a loam top.

In the flats the wash shows to a greater extent the rounding action of water, there being few large boulders; the major portion consisting

* Reports on the Federated Malay States for 1894.

of granite, slate, and quartz pebbles with the cassiterite in small crystals.

There can be no doubt in both of these instances where tin originally came from, as the lodes and the surrounding country show evidences of considerable denudation.

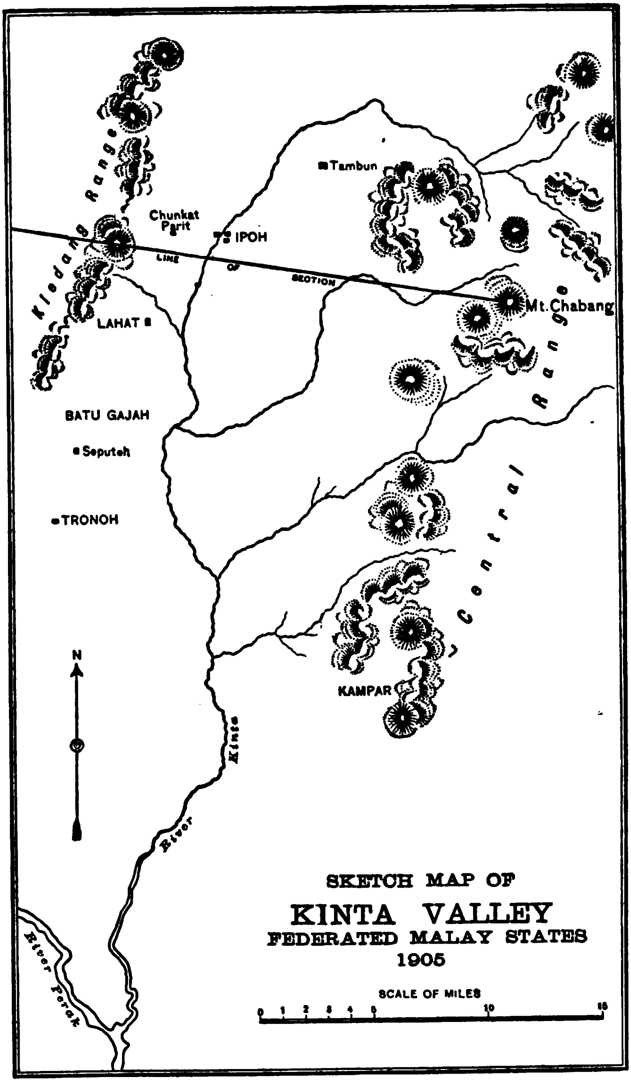
M. de la Croix, writing on the origin of alluvial tin ore in Perak, Malay Peninsula, says :—"All the granites are traversed by veins of quartz, which course through them in every direction, and which are the veritable deposits (gîtes) of the tin."

The Rev. Tennison Wood, disagreeing with the last authority and with the generally entertained belief of the uninitiated, does not think that the alluvial tin has been derived from lodes, or that such will be found. Elsewhere, however, he states, "nevertheless, in Northern Perak there are tin veins or true lodes," the true matrix of the tin being, in his opinion, "in the granite at its junction with the clays, where it has been disseminated abundantly in fine grains." "The whole of the granite of the Peninsula contains tin," says this author, "but it is at the junction of this granite with the palæozoic clays that the richest deposits of tin have taken place," and he suggests that one should "sink through the clay strata," where they have not been denuded, to tap these "second bottoms," as he calls them. Mr. Wood's theory is advanced, he confesses with some diffidence, to account for his supposed form of deposits. "Sublimation of the metal from its plutonic magma, its oxidation and condensation on the edges of the clay strata where metamorphism was not complete." * From his own observations the writer is of opinion that this occurrence of cassiterite, which must be of prodigious extent, and yet is so strangely unrecognisable, is chiefly in the form of an integral constituent of some varieties of the granite, such as "greisen," in certain zones ; and also in the shape of minute veinlets with quartz disseminated through such zones ; and, though occasionally irregular, shaped mannes of considerable size of more or less pure cassiterite, generally associated with limonite, are found outcropping in the bed-rock bottoms of alluvial workings, indicating the concurrent existence of some form of massive irregular deposits ; these latter are but exceptional segregations of minor importance to the main form of occurrence.

The following description of the Kinta District, by R. A. F. Penrose, jun., appeared in "Engineering and Mining Journal," June 20th, 1903 :—

"The Kinta District in Perak has no definite boundaries, but the name is a general term applied to an area in the southern part of the State of Perak, in the valley of the Kinta River, comprising a more or less enclosed valley about forty miles in length in a north and south direction, about thirty miles in width at its south end, and about five miles at its north end. To the east is the high granitic range forming the backbone of the peninsula, and rising in some places about 8,000 feet above the sea ; to the west is a lower granitic range rising

* Becher, W. H., *Min. and Mec. Mag.*, 1892.


Kledang Range
Chunkat Parit
Tambun
IPOH
LINE OF SECTION
LAHAT
Mt. Chabang
BATU GAJAH
Seputeh
TRONOH
Central Range
KAMPAR
N
River Kinta
River Perak
SKETCH MAP OF
KINTA VALLEY
FEDERATED MALAY STATES
1905
SCALE OF MILES
0 1 2 3 4 5 10 15

some 3,000 feet, and separating the valley from the Strait of Malacca. Between these ranges are lower mountains, and areas of limestone surrounded and partly covered with great tracks of alluvium. Twenty years ago the Kinta District was almost unknown, and Taiping and Kuala Lumpur were the great tin centres, but now it is the most important district on the peninsula. Among some of the more important mining centres in the district are Kampar, Gopeng, Batu Gajah, Tronoh, Cacha, Lalang, Papan, Lahat, Chongkat Pari, and Ipoh, the last being the commercial centre of the district; in fact, the alluvium over large areas has been completely stripped from the bed-rock in search of tin, and has been overturned in great piles, leaving the once fertile soil in a condition of desolation."

*An ideal section of the main geological features of the Kinta valley is given in Fig. 12. The valley is composed of a highly crystalline limestone, usually white in colour, sometimes gray; in fact, it may be called marble. It is always highly inclined and often contorted, and in some places is interbedded with shale. On the east side of the valley, near its contact with the granite, it forms a remarkable series of lime-

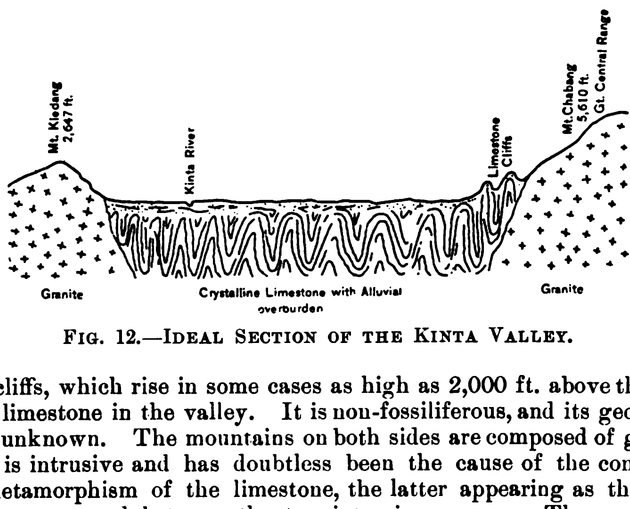


FIG. 12.—IDEAL SECTION OF THE KINTA VALLEY.

stone cliffs, which rise in some cases as high as 2,000 ft. above the level of the limestone in the valley. It is non-fossiliferous, and its geological age is unknown. The mountains on both sides are composed of granite, which is intrusive and has doubtless been the cause of the contortion and metamorphism of the limestone, the latter appearing as though it had been squeezed between the two intrusive masses. The granite is gray in colour, and often porphyritic, with large, well-formed crystals of orthoclase-feldspar, quartz, and biotite-mica. Tourmaline is very common.

The whole valley and a large proportion of the mountain slopes are covered with alluvium, which reaches a depth of 200 ft., as proved by mine-workings, and may be deeper in the middle of the valley, where there are very few workings; the average depth is about 30 ft. This

* W. Rumbold, "Trans. Amer. Inst. M. E.," July, 1903.

alluvium is composed of sand, pebble-beds and clay, and may rest either on a bed-rock of limestone or of "kong."

The limestone, from its steep bedding-planes and contorted structure, has been weathered to a very irregular surface, forming numerous little pinnacles and depressions the latter often extending into cracks of 10 to 20 ft. in depth, the whole forming an ideal series of natural riffles.

*Mode of Occurrence of the Alluvial Tin in the Kinta District.—In the larger valleys where the detritus from areas of different rocks has been mixed, the tin-bearing alluvium is commonly composed of a heterogeneous mass of white, grey, or red sandy or gravelly clay, often of a mottled character, containing numerous small quartz fragments about the size of a pea, together with pebbles and boulders of granite, gneiss, schist, pegmatite, limestone, etc. The alluvium in the hills, however, nearer its source, varies more in character, distinctly reflecting in different places the nature of the different rocks from which it has been derived. Frequently the alluvium is much stained with iron, and often contains large quantities of vegetable remains and partly lignitized wood.

The tin oxide occurs in the alluvium in a different way. Sometimes it is scattered through it from top to bottom in comparatively uniform quantities, sometimes it is in layers of rich ore separated by layers of lean or barren ground, sometimes it is richest on the bed-rock, and at other times higher up in the deposit. As a general rule, however, there is a covering or "overburden," as it is called, of barren alluvium from 10 to 40 feet or more in thickness, and the tin ground is found beneath this. The ordinary tin-bearing strata vary from 1 to 30 feet in thickness, though sometimes they reach over 100 feet.

At the bottom of the alluvium is generally either granite or limestone, though frequently where the tin oxide stops, barren alluvium or rock decayed *in situ* separates it from the bed-rock, so that the solid granite or limestone is not always seen. The limestone bed-rock is often leached in undulating surfaces with alternating protrusions and recessions, resulting in a series of natural riffles, behind which cassiterite has concentrated. This occurrence is well seen along the waggon road between Ipoh and Lahat, and is similar to the way gold has collected behind limestone riffles near Columbia in California. Stanniferous alluvium frequently occurs on ridges and hills as well as at lower levels in the valleys and creek beds, sometimes suggesting that since the formation of this alluvium there has been an elevation of the region followed by subsequent erosion, with the result that the older stanniferous alluvium occupies the higher places, while the younger alluvium, derived probably in part from the older deposits, occupies lower levels, in much the same way as the Tertiary gold placers of California often occupy the higher spots, and the more recent placers are found in the

* W. R. Rumbold, "Trans. Amer. Inst. M. E.," 1906.

TIN SLUICING, KINṬA, PERAK.

present stream beds. This may be true in some of the tin deposits, but it is necessary to distinguish between such occurrences and the cases where the tin deposits on the higher places are simply residual deposits formed *in situ* by the superficial decay of tin-bearing rocks, without removal of the tin from the region of its source.

NATURE OF THE TIN ORE IN THE KINTA DISTRICT.—The tin occurs in the form of cassiterite or oxide of tin (SnO_2) often well crystallized in tetragonal prisms with fine termination, though the fragments in the alluvium have been more or less rounded by attrition. The ore varies in colour from black or brown to grey, greyish-green, white, or transparent, but the commonest kind is of a dark brown colour with a resinous lustre. Sometimes the ore is angular, and in comparatively large fragments; but this is rare, and the common alluvial tin fragments range from the size of peas to that of sand grains or smaller; while efforts are being made to work tin ore that exists as a fine powder in the mud banks that line certain parts of the west coast of the peninsula.

The amount of metallic tin in the ore, as commercially mined, ranges from 69 to 73 per cent., an average of about 70 per cent. being considered very fair. The richness of the stanniferous alluvium varies much in different places. The average value of the alluvium worked in the Kinta District is probably about 1 per cent. of tin oxide, and the ground of this grade pays well to work if favourably situated. If the alluvium contains 2 per cent. of tin oxide it is considered exceptionally good ground, and with 3 or 4 per cent. it is considered remarkably rich. Sometimes thin strata in the alluvium are very rich in tin oxide, containing from 40 to 60 per cent., but this is very rare.

Minerals Associated with the Tin Oxide in the Kinta District.—With the tin oxide of the alluvium are associated much tourmaline, hornblende, wolframite, and magnetite, while in smaller quantities are found white mica, topaz, scheelite, sapphire, and it is said that in parts of the peninsula small quantities of thorium and cerium minerals have been found. Some beautiful transparent topaz crystals have been found near Tapa, south of Campar. Gold also has been found in small quantities in the tin alluvium. Certain other minerals, such as iron pyrite, chalcopyrite, bornite, and arsenical pyrites, which occur with the tin in the rock, are rarely seen in the alluvium, as they have decomposed, and mostly disappeared during the erosion of the rock, though rusty masses of these sulphides, partly decomposed and associated with quartz, often occur in alluvium which has not been transported far from its source.

Occurrence of Cassiterite in the Rocks of the Kinta District.—Though the tin mined on the peninsula comes practically all from the alluvium, yet cassiterite also occurs in various places *in situ* in the rocks of the region. It is most often found in granite, but also occurs in the limestone and sandstone. It has been worked in a few localities,

but none of the efforts have as yet been more than partially successful, and most of them have eventually failed, as the ore is in too scattered a condition to pay to work. It seems not impossible, however, that deposits may yet be found in the rock that can be profitably worked.

Where the tin is seen *in situ* in the granite, it occurs in pockets, small veins, or a combination of stringers intersecting each other in various directions in the form of a network, while elsewhere the rock is simply impregnated with particles and crystals of cassiterite over certain areas. The tin is associated with quartz, tourmaline, fluorite, and the other minerals already mentioned, especially iron pyrites and arsenical pyrites, which often occur in very considerable quantities, and smaller quantities of chalcopyrite. Cassiterite in the limestone is probably rarer than in the granite, as Chongkat Pari was the only case seen or heard of by the writer where it had been clearly proved to exist in that rock. At that locality tin oxide occurs both in the alluvium and in the limestone. In the limestone it occurs along a zone of fracturing, sometimes as an impregnation in the rock, sometimes as lenses or irregular pockets from 4 to 24 inches in width, and sometimes along the cracks in the rock, either longitudinally or transversely with the zone of fracturing. It is associated with large quantities of iron pyrites and arsenical pyrites, and smaller quantities of chalcopyrite and bornite, and some rhodochrosite. At Bruseh, near Tapa, in Perak, cassiterite has been found in thin seams and films along the lines of bedding in a soft, fine-grained friable sandstone, which bears every evidence of being a comparatively young rock, and it seems probable that the cassiterite in it was derived from tin-bearing solutions from the older rocks percolating along the bedding planes.

Origin of the Tin Deposits of the Kinta District.—The tin oxide in the alluvium has clearly been derived by erosion from the cassiterite in the rocks. As regards the cassiterite in the rocks, however, it may be said that in the granite the occurrence of the cassiterite in veins, stringers, network, etc., along lines of fracturing is strong evidence of aqueous deposition of the ore; while the occurrence as an impregnation in the rock where no marked fissuring occurs may be due either to concentration during a more or less molten condition of the rock, or to aqueous concentration in a solidified rock. It seems probable that the tin in the limestone was deposited from aqueous solution, in the same way as at least part of the cassiterite in the granite.

Mr. J. B. Scrivenor, Geologist to the Federated Malay States, has written the following account of the alluvial deposits at Taiping, in State of Perak, and published in the "Perak Government Gazette," 1904:—

"The physical features of the neighbourhood of Taiping are well marked; and on account of their importance they call for a short description here before dealing with the geological detail. The most imposing of these features is the range of hills east of Taiping, trending at first north and south, and then turning slightly to the north-west. It rises to three considerable peaks, Gunong Bubu, 5433·5 feet (I quote the names and elevations given on the 1901 Map of Perak, on the scale

of 4 inches to the mile); Wray's Hill, 3,347 feet; and Gunong Hijau, 4,751 feet 7 inches; while at the northern limit of the range is a smaller hill, Bukit Lara, 1,600 feet 7 inches. Between Wray's Hill and Gunong Bubu is a pass leading to Padang Rengas. It will be convenient to refer to this range throughout as the Taiping range. At the foot of the Taiping range on the west are several smaller hills, chief among which are Speedy's Hill, 964 feet, connected with the Taiping range by a spur; Scott's Hill, isolated, but sending out spurs of its own; and the hill on the southern end of which stands the Catholic church. Another range, less imposing than that overlooking Taiping, but, geologically, quite as interesting, lies eight miles as the crow flies north-west of Taiping. This is the Semanggol range, culminating in Gunong Semanggol, 1,279 feet 2 inches, and ending on the north, at least as far as concerns us now, in three small isolated hills, the most northerly being Bukit Merah. Between the Semanggol and Taiping ranges are several small elevations. At Padang Rengas we have an excellent example of a feature characteristic of the Peninsula, the limestone hill Gunong Pondok, connected with the Taiping range by a spur below the Waterloo Estate, but elsewhere rising sheer from the flat floor of the Padang Regas Valley. For the rest, the area in question, with the exception of that part in Selama, consists entirely of a vast alluvial flat, from which has been extracted that wealth of tin ore which has made the district of Larut justly famous.

"Nearly every writer who has dealt with the geology of the Malay Peninsula has described the famous stanniferous alluvial beds at some length. I do not think it is necessary to give a detailed account of the mineralogical constitution, the order of deposition, and the thickness of the various strata composing the mass of these presumably recent deposits. I will merely dwell on certain points which I consider of interest and importance, and some of which, as far as I am aware, have not been touched upon by previous writers.

"The first of these points is the nature of the boulders and pebbles in the tin-bearing karang, a matter of extreme importance, since thereby it is possible to obtain valuable evidence of the source of the cassiterite. In all the mines I have visited in the neighbourhood of Taiping small heaps of pebbles were to be found washed from the karang in the sluices, and almost invariably they proved of interest.

"Another point is the multiplication of the karang stratum. Evidence of this was seen in two mines in Larut, one under Speedy's Hill, where it was pointed out by Mr. Cumming that in working the mine they had sunk through one bed of karang and found another bed separated by alluvium consisting to some extent of light grey clay, and which there was reason to suppose joined the higher bed some distance off; the other, as shown to me by Mr. Cumming, in the Gugop district, where at first a few feet near the surface were worked for tin but later the mine was sunk to a deeper bed of karang, of great thickness, and separated by strata and fine sand. Moreover, Mr. Cumming informed me that in this mine one of the intervening beds, a thin layer

of coarse gravel, was found to contain tin in workable quantities ; so that there are really three beds of karang here.

"A very interesting mine, in connection with the question of the derivation of the cassiterite, is now being worked by Messrs. Tate and Cumming at Ayer Kuning, close to the Small-pox Hospital. On the west of the mine is the inconspicuous changkat on which the hospital stands ; and a few furlongs to the east are the granite hills of the Taiping range. Under the soil, in the western part of the mine, there are 15 feet of white overburden, which to the east give way to a more clayey alluvium with numerous tree trunks. The white overburden consists of loose kaolin, fragments of decomposed pegmatite, white and grey quartz, and abundant pebbles of the shale and sandstone series bleached to a light grey. There is a considerable quantity of tourmaline in large crystals, which, together with associated quartz grains, probably came from pegmatite veins ; and in places the alluvium is very micaceous. It is remarkable that, in spite of the proximity of the granite hills, the distance between the mine and the hills being much less than between the hills and the Kota mines, where pebbles of granite occur ; in spite of this, there was not a pebble of granite to be seen when I visited the mine. Again, Mr. Cumming informed me that in working the mine they find that the karang is shallow on the west, that is near the changkat, while it gets deeper towards the hills. Now these facts can only point to one conclusion, and that is that the white overburden and the karang with the cassiterite have been derived from the small changkat on which the hospital stands ; and further, judging from the nature of the alluvium, it may be concluded that the changkat owes its existence to a hardening of the shale and sandstone series, over and above whatever may have been effected in this direction by the main granite mass, consequent on the intrusion of a mass of pegmatite, isolated on the surface, but certainly connected in depth with the other igneous rocks of the Taiping range.

"Another point is the cementation of the alluvial karang by iron oxides, which has taken place in varying degrees. In some cases the karang is merely discoloured by limonite, and can hardly be said to be cemented. At others, as for instance in Hong Hap's mine at Kota, the karang, although cemented, is friable. Extreme cases were noticed in two localities, one on the Jenah Valley, the other in the Relau Valley, at Selama. In the Jenah Valley the karang was found in one place to be so firmly cemented that it needed a smart blow of the hammer to break it. At Selama, the base of a bed of karang, resting, as far as could be learned from the available evidence, on decomposed shale and sandstone, was also firmly cemented. The karang here, which is exposed on a public dumping ground, is rich in tin oxide, which can be seen projecting from the surfaces of the blocks of ironstone as rounded grains of cassiterite. This cementation may possibly be due to the oxidisation of pyrites ; but a much more probable, and I believe the correct, explanation is that it is owing to the oxidisation in place of iron carbonate, which was deposited as chalybite from percolating water.

"My last point in connection with the alluvial deposits is the nature of the kong, of which there are, in the Larut district, two distinct kinds. The first is a mixture of kaolin and quartz in varying proportions, according to the percentage of these minerals in the pegmatite from which the kong was undoubtedly derived. This true kaolin kong can be seen in two mines under the Sungei Ralau Tujoh. The other kind of kong is found in the mines of the alluvial flat at Kamunting and Kota, where it is found to consist of a dark grey, red, light grey, or white clay, which may contain fragments of rock, as for instance at the Chop Hiap Ju mine in Kamunting, where a borehole revealed angular fragments of sandstone and fine conglomerate at about 12 feet from the surface of the kong, and at Kong Sing Lees mine at Kota, where I was informed that the kong is in some places stony.

"In the existing literature mentioning the kong it is treated as if it were of the same nature, and composed mostly or entirely of kaolin. Thus Prof. H. Louis describes it as being generally an impure kaolin formed by the decomposition of granite *in situ.** M. De la Croix† only speaks of the kongtay as a white plastic clay, which is very pure kaolin. The Rev. J. E. Tennison Wood calls it kaolin, or partly decomposed granite.‡ Mr. P. Doyle§ speaks of it as a peculiar white clayey substance which becomes friable on drying. M. Collet describes the kontay as 'kaolin (hydrated silicate of alumina),' as being nearly always white or slightly tinted with blue, but sometimes dark red or grey-blue when it rests on the schists; and further, this author affirms that such kontay is composed nearly entirely of kaolin.

"I selected two specimens of kong, one from one of the mines under the Sungei Ralau Tujoh; another of white kong from the Chop Hiap Ju mine at Kamunting, a mine which is well out on the alluvial plain. Microscopic examination of this material under a high power showed that the former specimen consisted entirely of minute scales of kaolin, with the characteristic irregular shape sometimes inclining to a hexagon, the perfect cleavage parallel to the base, the index of refraction about the same as balsam, and the weak double refraction; while, on the other hand, the Kamunting specimen consisted of a mass of quartz granules, possibly some felspar, an occasional zircon, and a few grains of brown tourmaline. There was nothing in the slide that could be called kaolin.

"Thus, then, some of the kong at any rate contains little or no kaolin, which will explain the failure of the manager of the Chop Hiap Ju mine to use it successfully as china-clay. Of its real nature I do not think there can be any doubt; but to demonstrate this I must

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* J. A. Phillips and H. Louis, "A Treatise on Ore Deposits." London, 1896, p. 591.

† Op. cit.

‡ J. E. Tennison Wood, "Physical Geology of the Malay Peninsula," "Nature," Vol. XXXI., p. 152, 1884.

§ P. Doyle, "On Some Tin Deposits of the Malayan Peninsula," *Quar Jour. Geol. Soc.* XXXV., 1879, p. 229.

anticipate somewhat and draw attention to the weathering of the shale and sandstone series.

"I have already described how in the mine near the Small-pox Hospital the shale and sandstone is bleached to a light grey colour; and how under the hill on which stands the Catholic church the sandstone is bleached completely. Further, in the railway cutting at Pandok Tanjong the shales are weathered to a pinkish, mottled, or white clay; and white clay derived from the same source, and similarly retaining the bedded structure, can be seen in the small cuttings between Pandok Tanjong and Kamunting. At Bukit Merah, too, the whole series is lighter in colour than at Semanggol, owing to weathering. Weathering in red-coloured rock is easily explained by the presence of oxides of iron. But for perfect examples of this weathering it is necessary to go outside the area under consideration and look at the sections of similar shales between Bidor and Sungkai, where large masses *in situ*, retaining their bedded structure plainly, are bleached in some cases to pure white, in others to pale purple, grey, or green. It is interesting also to note that sedimentary rocks in Cornwall, not far removed from these petrologically, have suffered an identical process of bleaching; and that so far no satisfactory explanation of it, so far as I am aware, has been forthcoming.

"In view of the above facts, the simplest, and, as I believe, the correct explanation of the kong at Kamunting is that it is the surface of the shale and sandstone series, bleached either before or after the deposition of the alluvium, and after the deposition of these beds, disintegrated by water percolating through the loose gravels above to form plastic clay. It is possible that a portion of this kong immediately below the karang represents material that has been derived from the shale and sandstone series at some place removed from its present resting place; but the angularity of the fragments of sandstone and conglomerate shows that they at any rate, and the surrounding clay, represent the series *in situ*.

"There is no evidence to show that the white kong, or the grey or red, at Kamunting, has been derived from the granite range; and, on the other hand, there is plenty of evidence that the kaolin kong under the Ralau Tujoh was formed *in situ* by the decomposition of pegmatite. Therefore, with the possible exception mentioned above, we may say that the kong of the Larut mining district represents pegmatite and the shale and sandstone series decomposed *in situ*."

The *Selangor Government Gazette* of September 14, 1906, contains a report by the Imperial Institute staff on a specimen of washed alluvial tin ore from the land worked by the Sempam Tin Mining Company, Pahang.

The ore consisted principally of a mixture of cassiterite, ilmenite and monazite. The latter mineral was in the form of whitish opaque grains unlike ordinary yellow monazite such as is found in Brazil and in Carolina, United States of America. The washed ore as received was found to contain tinstone equivalent to 50·86 per cent. of metallic tin,

and 1·51 per cent. of thoria. The following is the complete analysis of the ore :—

	Per cent.
Thoria ThO_2	1·51
Stannic oxide SnO_2	64·53
Titanic oxide TiO_2	6·49
Zirconia ZrO_2	·48
Ferric oxide Fe_2O_3	3·09
Alumina Al_2O_3	·24
Cerium oxide Ce_2O_3	3·41
Lanthanum oxide La_2O_3 } Didymium oxide Di_2O_3 }	4·38
Manganese oxide MnO	·36
Ferrous oxide FeO	2·36
Lime CaO	·31
Niobic oxide Nb_2O_5 } Tantalic oxide Ta_2O_5 }	2·86
Silica SiO_2	2·44
Phosphoric anhydride P_2O_5	3·54
Loss of ignition	·81
	96·81
Metallic tin	50·86

The monazite was separated from the other constituents, first by magnetic means and finally by hand.

The "concentrate" thus obtained was analyzed with the following results :—

	Per cent.
Thorium oxide ThO_2	8·38
Cerium oxide Ce_2O_3	25·46
Yttrium oxide Y_2O_3	2·80
Lanthanum oxide La_2O_3 } Didymium oxide Di_2O_3 }	32·72
Ferric oxide Fe_2O_3	2·78
Aluminum oxide Al_2O_3	·84
Calcium oxide CaO	·61
Phosphoric anhydride P_2O_5	23·92
Silicia SiO_2	·92
Moisture H_2O	·14
Loss of ignition	1·14
	99·71

The results of the analysis of the separated monazite show it to be rich in thoria, of which 8·38 per cent. was present.

The opacity of the grains of monazite is probably due to slight decomposition, as is indicated by the presence of 1 per cent. of water and by a deficiency of phosphoric acid, the amount of which is 24 per cent. instead of 28 per cent. as would be expected in a monazite of this class. A similar deficiency of phosphoric acid in relation to the rare earths present was also noted in a previous specimen of heavy sand from Tringganu which was sent to the Imperial Institute by the Government geologist.

The proportions of the principal constituent minerals in the sample are approximately as follows :—

	Per cent.
Cassiterite - - - - - - - - -	65
Ilmenite (including rutile and magnetite) - - -	16
Monazite - - - - - - - - -	13
Columbite - - - - - - - - -	3

Small quantities of other minerals were present but were not estimated.

Conclusions and Recommendations.

By magnetic concentration the constituent minerals of this tinstone sand could be separated, and if this were done both the tinstone and the monazite must be of commercial value. If, however, the ore were smelted in its present condition the monazite would be lost in the slag. In view of the fact that the monazite is rich in thoria, its separation from the sand on a commercial scale is worth consideration. Taking the market price of tin at £180 per ton, the value of this ore as a source of tin is about £80 per ton in its present condition. The concentrated monazite would be worth, at the present rate, about £37 per ton.

* CHINESE-OWNED TIN-MINES are much more numerous than may be generally supposed, and may be enumerated as follows :—

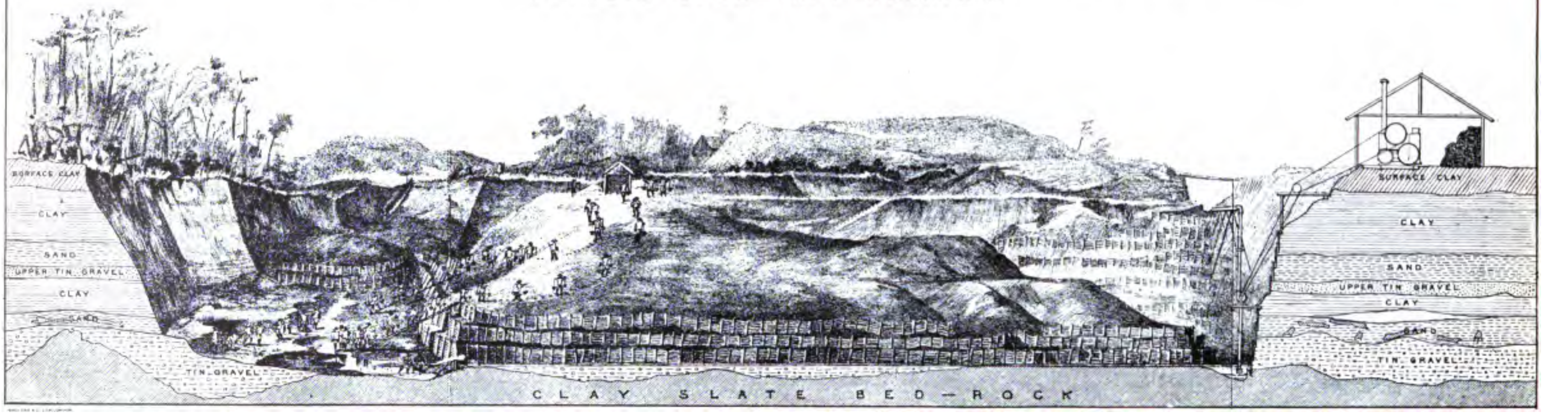
In the Kinta Valley chiefly.

	Mine.	Owners.	Coolies.
1.	Kampar - - - - -	Foo Choo Choon	1,200
	Lahat - - - - -	,,	1,000
	S. Raia and Pulai - -	,,	1,000
	Chemoh - - - - -	,,	2,000
	Chenai, T. Koyan - -	,,	500
	Tronoh - - - - -	,,	1,000
	Papan - - - - -	,,	800
	Salak - - - - -	,,	200
	Tapah - - - - -	,,	200
	Kumunting - - -	,,	2,000
2.	Kota - - - - -	Ah Phin Bros.	7,500
	Assamkumbang - -	,,	
	Gopeng - - - - -	,,	
	S. Siput - - - - -	,,	
	Kampar - - - - -	,,	

* C. Duncan, *Straits Echo*, 1905.

ALLUVIAL TIN MINE, MALAY PENINSULA

CHINESE OPEN-CAST WORKING.



	Mine.	Owners.	Coolies.
3.	Menglembu	Chan Choon Weng	5,700
	T. Rambutan	"	
	Chenderiang	"	
	Papan	"	
	Tronoh	"	
	Assamkumbang	"	
4.	Chenderiang	Eu Tong Sen	3.000
	Tekka	"	
	T. Rambutan	"	
	Kampar	"	
5.	Temoh	Chan Yek Theng	3,000
6.	Kamunting	Ng Boo Bee	3,000
7.	Tambun	Leong Fee	1,000
8.	Kacha	Loke Mun Yeung	1,000
9.	Kacha	Chang On Siew	1,000
10.	Kinta District	Li Thung Sen	1,000

Chinese miners employing less than 1,000 men have been left out of the reckoning; but it may be safely assumed that about 70,000 Chinamen are earning their living on small mines and by fossicking in small parties in all parts of the States. The ten Towkays above-mentioned employ about 36,000 coolies, and it is no exaggeration to say that the gross value of their mines is represented by a sum exceeding thirty millions of dollars.

European Mines.

Mine.	Owners.	Coolies.
Gopeng	Limited Liability Co.	200
New Gopeng	" "	200
Kinta Limited	" "	200
Red Hill	" "	200
Pusing Lama	" "	200
Papan (stopped work lately)	" "	—
Tronoh Mines (two-thirds Chinese)		1,000

The following revision in the export duty on tin and tin ores recently came into force in Selangor (November 1st), Perak and Negri Sembilan (November 6th), 1903 :—

TIN.

	Per bhara.
Alluvial.—When the price of tin exceeds $31 per pikul up to $32	$10.50
For every additional $1 per pikul in the price of tin up to $38	25 cents.
For every additional $1 per pikul in the price of tin thereafter	50 cents.

CHAPTER IV

THE ALLUVIAL TIN DEPOSITS OF BANCA, BILLITON SIAK, SUMATRA, SIAM, BRITISH BURMA, AND FRENCH INDO-CHINA.

*THE most conspicuous tin-producing part of the Dutch possessions in the Indian Archipelago is undoubtedly Banca, where tin was discovered as far back as 1710; but since 1821, when the Dutch became fully possessed of this territory, Banca has been a very important factor in the tin-mining industry of the world.

The tin deposits of Banca and Billiton, typical islands of the Indian Archipelago, are mainly alluvial; several unsuccessful attempts have been made to work the lodes and stock works in these islands from time to time.

In the island of Banca the geological conditions resemble those of the Malay Peninsula. The bed-rock consists of granite masses flanked by Silurian slates. Tin ore has been found occurring as impregnations in the granite and also as veins in the slate, but these deposits are unimportant. The tin-wash consists mainly of fragments of granite, "schorl," and sandstone. The bed-rock nearly always consists of granite more or less decomposed. A section of an average stream-tin deposit shows above the bed-rock three feet of tin-bearing gravel overlaid by red sand, followed by red clay, then coarse sand with pockets of clay, layers of fine sand with a little fine tin ore. The average overburden is from 25 to 35 feet; shallow diggings are prospected by pits, deeper ones by systematic boring. In 1903 and 1904 about 7,000 men were employed in the mines of Banca, and produced an average of nearly 72 per cent. of a ton per man. There is water for working in the lower valley diggings but eight months each year, and for only five months in the upper diggings.

The following account of the tin deposits of Banca is taken from a book, "Banca and its Tin Steam Works," by P. Van Diest, translated from the Dutch by C. Le Neve Foster, 1867:—

"The stream tin occurs in valleys and on plains which are generally alongside of the valleys, from where the tin is derived; the true tin ground, which consists of tin stone mixed chiefly with quartz gravel, is found resting immediately upon the original bed of the valley. It is

* The Alluvial Tin Deposits of Siak Sumatra; "Trans. Am. Inst. Min. Eng.," Vol. XX., 1892, pp. 50–84.

rarely more than 3 feet, and usually 1 to 2 feet thick; above the tin ground there are various layers. First layer of coarse sand, then a bed of clay, red, white, or black in colour. Above this a good deal of coarse sand is met with, sometimes with much clay. Above the tin ground there are usually beds of sand, upon which follow beds of clay, the fine light particles of which were held longer in suspension than the sand. Between them there is sometimes a thin bed of sand containing a little tin. The total thickness of the over-lying bed is seldom more than 33 feet, and usually from 16 to 33 feet; above these beds there is a layer of soil in which the river or brook takes a shallow serpentine course. The tin-bearing valleys are usually broad and marshy, especially in the granite country.

"The bed of the river is, as a rule, immediately above that of the original valley; the deposits on the plains consist merely of a single bed, the whole of which is tin-bearing. Sometimes, however, a true tin ground is found covered by a layer of soil, and occasionally also by a thin bed of clay. These deposits, which are not in the valleys, are called Koolit-grounds in Banca."

Whenever it is proposed to begin a stream work, a dam is made at a certain distance up the valley. A reservoir is thus made, and leats coming from it are dug on both sides of the valley.

A large portion of the lower part of the valley is then laid dry by another leat or drain, which is usually dug near the bottom of the valley. This drain runs some distance below the first pit or kollong. The other leat should be placed as high as possible, and serves to bring water to wash away the overburden and drive the water-wheels to pump the kollongs dry. This leat is called the "bandar"; as soon as these arrangements are completed the working of the first kollong is begun.

The work is nearly always carried up the valley. The kollongs are usually oblong, and so long that it takes years to dig them out and obtain the tin. A workman can remove on an average of nine hours' work per day 350 to 530 cubic feet of ground to a depth of 3 feet 3 inches. When the upper part of the overburden has been removed, moveable launders are arranged with streams of water running through them; a number of workmen then shovel the gravels into these launders; for this purpose they use shallow baskets with long handles; the baskets are filled and placed within reach by workmen who are on a lower level, and who loosen the ground with crowbars and "patjols."

On an average two men, one filling baskets and the other emptying them only, can remove a piece of ground 6 feet 7 inches square to a depth of 6 feet 6 inches, or about 282 cubic feet.

The beds which lie below the level of the stuff removed in this manner cannot be got away by means of water, but have to be carried up. The tin ground itself is carried to a separate place where water for washing it can be conveniently brought; looking from the side of the kollong these carriers seem to form an endless chain.

Nothing but chain pumps to overshot water-wheels are used in Banca. They are arranged in a very practical manner, and

their construction agrees perfectly with what theory shows to be correct.

On an average 141 cubic feet of water can be raised 16 feet by a pump which requires 106 cubic feet of water to work it. Four hundred and seventy-seven cubic feet are pumped up in a minute out of a kollong 14 feet 9 inches deep by three water-wheels.

Underneath the tin ground rock in places is met with. It is much decomposed, and called by the Chinese "kong," *i.e.*, empty.

The kong consists entirely of decomposed granite. The felspar of the granite is usually entirely decomposed with kaolin; the mica is generally entirely weathered away. The tin gravels are sluiced by a powerful stream of water, in which the stuff is stirred about in small quantities, the tin settling down and cleaned by drawing it up against the stream by means of the patjol; experienced workmen do this very nicely and smoothly.

In the province of Soengei-Liat, the ordinary mines remove 10,600 to 14,000 cubic feet a year for each person employed.

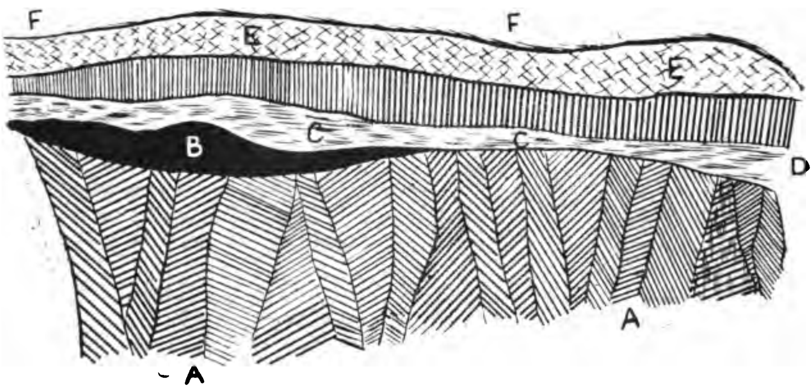


FIG. 13.—SECTION ALLUVIAL ORE DEPOSIT, BANCA.

A. Decomposed rock *in situ*.
B. Tin ground (tin stone with pebbles of vein stone).
C. Bed of coarse sand. Sometimes mixed with clay.
D. Running sand and beds of sand mixed with clay in varying proportions.
E. Beds of clay sometimes mixed with sand and soil.
F. Surface sub-soil.

GEOLOGY OF THE DOEREN DISTRICT.—At the two hills, Lampor and Sambong Giri, the beds of slates are hardened and very much bent and contorted, causing an apparent multiplication of alternate blue and white layers; near the granite we find a porcelain jasper, lydian stone, and a hard slate.

To the north of the mining district of Doeren a mica schist occurs; the slate here contains a great deal of oxide of iron, which occasionally appears as a bed of iron ore. In the province of Blinjoe especially,

these ferruginous slates occupy a considerable extent of country along the borders of the granite.

Near Braug, in the province of Muutok, white tin stone is found to occur in veins of quartz and also in separate veins; in this province the bed of ferruginous slate is very limited. The granite has broken through sandstone, which has suffered considerable alteration.

Granite rocks of Banca:—The granite at Cape Pocnce is less coarsely grained than that of Obi Lui. The mica is more prominent and brown in colour; the felspar a brilliant white, sometimes a dull green, with small veins of quartz and tourmaline.

At Cape Raja little veins are met with consisting of a soft silicate of alumina mixed with quartz. Veins of a fine-grained granite and sometimes found in ordinary granite, a little copper pyrites with a coating of carbonate of copper, were observed in some of the joints; between Cape Lajang and Cape Raja is the Bay of Soengei Liat, in which the Liat River discharges into the sea.

Near Sambong Giri in breaking a piece of sandstone I saw unmistakable crystals of tin in the joints; this was the first time tin had been found in lodes. In a trench cut at Sambong Giri, a lode was discovered dipping at an angle of 70 degrees, much the same as the beds of quartz, etc.; five feet below the surface the lode opened out, but not for any great length; rich tin stones a foot thick were obtained from it. The sandstone beds near this deposit of tin are contorted.

From all the investigations made, the following inferences may be drawn with safety:—

(1.) In Northern Banca tin occurs in the granite in various ways, and over a large extent of country.

(2.) The rocks which surround the granite are impregnated with ore and other minerals occurring in the granite for some distance, usually not more than about one mile and a quarter.

(3.) The materials are chiefly deposits in little veins or bunches in the direction of the planes of bedding or in the joints.

(4.) It is chiefly sandstone which takes up these minerals where the rock appears to be most metamorphosed. If, on the one hand, the peculiar occurrence of tin in the rock enables us to explain the great extent and uniform thickness of the stream tin deposit, on the other hand it enables us to surmise that no regular workable tin lodes occur in Banca.

The first thing in searching for stream tin in Banca is to trace the boundaries of the granite. Then carefully examine the rocks which occur round the granite in order to be satisfied that the valleys to be operated on are most richly filled with stream tin.

Concerning the origin of the tin deposits found in the Island of Banca, M. De Groot, chief of the Mining Department of the Dutch East Indies, in a letter to Sir R. J. Murchison, as far back as 1863, writes as follows:—"Twelve years ago, when I first arrived in Java, it was generally considered that the stream tin found in the Island of Banca was not derived from veins in the granite of the island, but from mountains on the continent of Asia, whence it had been washed down

to the bottom of the sea, and that the sea-bottom had been subsequently upheaved so as to form the island of Banca. This supposition appeared to me erroneous, and I therefore endeavoured to collect facts bearing upon the question. In 1860 I inspected all the stream works in the island, and found in the district of Pancal-pinang three parallel veins running nearly east and west, one of them containing tin ore in grains like those in the stream works. In 1862 I surveyed the Jeboes district and found grains of tin ore disseminated in granite. I also found that in every river that was streamed for tin the largest grains were found nearest the hills, and that further away towards the sea they gradually became smaller. Now, as the rivers of Banca run from the interior in all directions towards the sea, these facts proved that the stream tin is the detritus of the rocks and veins containing tin-ore occurring on the island."

With regard to the conditions of labour in the tin islands, it is officially pointed out that there are in Banca many thousands of miners, consisting mostly of the lowest and most disorderly classes of Chinese, and that nevertheless order is satisfactorily maintained in the island, which occupies an area of 200 square geographical miles, by a scattered police force of 244 Malays. Some ten years ago there was a sort of a mutiny, but it was quickly suppressed. It is a fact, however, that within the past few years there has been a falling-off in the number of Chinese coolies imported into Banca. In 1890 the number of coolies employed was about 6,500, but in that year the regulations affecting tin mining were modernised, with the result that gradually the number doubled, until in 1899 it reached 12,107. In the past two years, however, the arrivals have fallen to about 900 a year, and it is probable that this is due to the competition for Chinese labour in other parts, not especially South Africa, but rather in the tin mines of the Straits Settlements. It has now been decided to render the conditions of the Chinese labourers in Banca more easy by raising the amount paid by the Government for the tin delivered from the mines by 25 per cent., though as apparently this increase is to be paid to the Chinese labour contractors, each of whom supplies and controls a number of miners, it is doubtful if the actual labourers will obtain any considerable part of it.

Billiton.—In Billiton, also under the Dutch Government, the geologic conditions resemble those in Banca.. There are granite masses surrounded by quartzites, schists, and slates of Silurian age. Some tin is obtained from ledges that occur both in the granite and in the quartzite, but the greater part of the tin comes from alluvial deposits. In 1903-4 about 8,000 men were employed here, the output averaging per man a little under seven-tenths of a ton of tin. The prospecting is done very systematically, and is in charge of a corps of European engineers, who test the fields in advance of the mining operations by boring first at intervals of, say, 100 yards, and supplementary holes are made from 20 to 25 yards apart to ascertain the course, average thickness and character of the pay gravel. The contents of each hole is carefully washed and the tin ore weighed, and from these results calculations as to the probable yield of the ground are made. No lode

mining of importance has been undertaken. As far as the author is aware, there is no British Company operating in either Banca or Billiton, and the mining there can be regarded as practically a Dutch monopoly.

* In the small island of Singkep, close to Billiton, stanniferous alluvial deposits occur in some of the valleys, notably in those of Daba and Jankang; these are worked by a Dutch company, the Sinkep Tinmaatschapij, who employ about 450 miners.

(1) The tin deposits of Siak in Sumatra were leased † to a Dutch syndicate "for the extraction of tin and other minerals which appear in that part of the dominions." All the inhabitants working the tin-deposits in this region are obliged to pay a tax to the Sultan on the tin produced.

Sumatra is divided longitudinally by volcanic ranges into the east and west coast country. The west coast is a narrow strip of land 20 to 30 miles wide, underlaid, according to Dutch geologists, with granite; in places it is covered with alluvium and coral formation, sandstones, slates and volcanic rocks. East Sumatra is a generally low and slightly undulating country with superabundant rainfall, and little is known of its geology in consequence.

The tin-fields of Sumatra are approached by steamers of 12 feet draught, running from Singapore across the Straits of Malacca to Brewer Straits, up the Siak river to Benkalis, then south to Siak and east to Packanbarve. The distance up the river to Packanbarve is, according to the captain of one of the steamers, 120 miles. Beyond Packanbarve the Siak river becomes very sinuous and shallow, necessitating the use of *bloncong*, or partially covered canoes of a similar type to that used on some streams of South America. These canoes are propelled by poling or rowing as the case may require.

The cost of transportation—part by steamboat, part by canoe, entailing the breaking of bulk, the use of store-houses, &c.—is naturally a heavy charge against any enterprise commenced in this district. owing to the risk of floods, drift timbers and other incidental dangers. Thus it happens that any enterprise undertaken near the interior of Sumatra is for the present confronted with rather formidable obstacles and disadvantages, involving heavy initial costs which can be offset only by extraordinary richness of the natural resources to be developed. The present centre of operation in the eastern tin-fields is Kotta Rannah, lying about 300 feet above the sea, and connected by a track not more than 15 miles long with the Siak river station Getti. Over this track all freight is carried on the backs of the native Malays. The track is bad and presents many difficulties. As compared with Banca, Billiton, and other tin-producing competitors, Kotta Rannah, owing to the transfer difficulties referred to, cannot compete favourably at present. The underlying portion of this part of the country, so far as can be judged

* Phillips and Louis, "A Treatise on Ore Deposits."

† The Alluvial Tin Deposits; Siak, Sumatra. "Trans. Am. Inst. Eng.," Vol. XX., 1892, p. 50–84.

from the colour and nature of the soil on the paths, is sandstone. At and east of Getti an indurated calcareous clay, full of cypridenas and other small shells, forms the shores of the Tapong Kiri. The clay matrix surrounds rounded quartz granules, from the size of a pin's head to that of a pea, and more angular and partly kaolinised pieces of felspar. Throughout the mass occur carbonised vegetable remains and some shells. Inland, up and down the Siak river and west of the town of Siak, the soil is very clayey, so much so, in fact, that tobacco-growing has been abandoned on account of it.

A comparison of the foregoing account of Sumatra with what is known of adjacent countries shows that similar geological conditions have prevailed in the Malay Peninsula, Karimon Islands, Western Borneo, Sinkep, Banca, and Billiton, and as the search is extended, this belt of a geological unity will unquestionably be widened. Quartzites, quartz conglomerates, quartz, schists, hornblende schist, siliceous sandstones, clay-slates, with granite and local basalts, form the prevailing rock formations.

The Kotta Rannah-Rambai stream-system and banks for alluvial tin possess a universally shallow and similar alluvial covering.

The covering over the angular quartz gravel averages 3½ to 4 feet, and consists of about 6 inches of humus and 3 to 4 feet of yellow sandy clay. The underlying angular quartz gravel is itself divided into two separate layers. The upper 8 to 10 inches consists of angular fragments of white quartz of 3 inches maximum and 1 to 1½ inch average diameter, largely intermixed with carbonised wood. It carries very small amounts of fine cassiterite, and considerable magnetic and red oxide iron-sand. In the lower layer, which is separated from the upper by a thin, often only slightly-marked seam of grey clay, from 1 to 2 inches in thickness, the nature of the quartz gravel is the same as above; but carbonised wood is absent, the amount of iron-sand is smaller, that of cassiterite is larger. This layer is locally known as the pay seam. Small crystals or crystalline fragments of spinel and ruby, but no tourmaline, garnet, topaz, or mica were noticed. Both the tin-ore and the quartz show little average wear of corners and edges, indicating that they have been transported a short distance only.

Underlying the quartz gravel is a tough grey or greenish grey clay of varying thickness, which gradually passes into decomposed rock in places from 3 to 4 feet thick. Below this lies the true bed-rock, an impure sandstone of the nature already described.

The tough grey clay underlying the quartz-gravel is the bed-rock for working purposes.

As is usual in creek-beds and their adjacent banks, unevenness in the bed or pot-holes occurs, in which there is generally an extra accumulation of tin-ore. In figuring the thickness of the gravel and its corresponding richness they must be considered. By a simple computation (the tons of quartz-gravel worked from a given area being known) one can arrive at the conclusion that the average thickness of the pay-quartz gravel, including the pot-holes, is about 6½ inches, or 0·54 feet, in the Batang creek, with an average overburden of 4·93 feet.

This creek was selected to begin operations on as offering the best inducements. The pay-gravel yielded "black-tin" (averaging 70 to 72 per cent. in "white" or metallic tin) at the rate of $2\frac{7}{16}$ pounds per ton of 2,240 lbs., or 0·12 per cent. Calculated on the total amount of ground excavated, including the stripping, this would be 0·476 pounds black, or 0·348 pounds white tin per cubic metre excavated. In Banca the same amount of excavation (according to Von Diest) yields $2\frac{2}{16}$ to $3\frac{1}{3}$ kg. black, or $1\frac{3}{4}$ to 2·03 kg. (2·95 to 4·46 lbs.) white tin.

The relative proportion of pay-gravel to entire stratum reserved is at Banca 3 to 33 feet; at Kotta Rannah 0·54 feet to 5·47 feet, or practically the same. The advantage of a lighter covering in the latter place is neutralised by a reduction of yield in about the same proportion. The economical limit of mining is naturally different in the two places, depending largely on surrounding conditions, mechanical facilities, and the cost and efficiency of labour.

From geological indications it is apparent that the Kotta Rannah-Rambai alluvial tin-field is of comparatively recent origin, being derived from the broken-down outcrops of stanniferous quartz-veins which occur in the underlying and adjacent impure sandstone, in a probably north-west and south-east direction. They are likely to extend at intervals into adjoining districts Unquestionably there are other and similar belts in Siak. Tin-ore has been found in the streams of the north-west part of the concession and beyond, near to Rokhan river, but little is as yet known as to the extent and value of the lodes. A systematic tracing of the belt may lead to the discovery of richer fields in Siak than the one described.

The hours of work in Siak are from 7 to 11 a.m. and from 1 to 5 p.m. Coolies in Siak are paid once a month, nominally $2.50, but $1.50 is kept back on account of the advance made on enrolment, leaving the coolie $1 in cash per month during his year of employment. In addition to the Chinese miners, small numbers of the Javanese coolies are employed in Siak for making roads and grubbing out the roots of trees, and the native Malays find work in clearing the jungle and forest and carrying supplies over rough roads, etc., etc.

The Banca miners of alluvial tin distinguish two classes of work: the mountain stream work, called kulit, and the working of valley places and flat, called kollong. In Siak, Sumatra kulit-work only exists. This work is performed, after the necessary preliminary cleaning and grubbing, by Chinese coolies, and consists in first diverting the stream, and then making, stream upwards, a series of rectangular excavations (kulit).

TIN DEPOSITS OF SIAM.

Tin is the only metal the working of which is of any importance in Siam. Tin is found in small quantities in the valley of the Nam Sak river and in various places in Northern Siam, but all the deposits of importance are derived from, and lie adjacent to, the great line of granitic upheaval which forms the boundary range between Central Siam and Tenasserim, is the backbone of the Malay Peninsula, and may be traced

down to the Dutch islands of Billiton, Banca and Sinkep. This great line of granite is the source of practically all the vast alluvial deposits of tin which are found in Siam and the British and Dutch East-Indian possessions. The Siamese territory is probably as well off in this respect as either the British or Dutch, and the deposits are very widely distributed. Of the Siamese possessions in the Malay Peninsula, tin is at the present time being worked in the following provinces :—

East Coast.	*West Coast.*
Ratburi.	Kra.
Bangtaphan.	Renong.
Langsuan.	Takuapar.
Chaiya.	Panga.
Bandon.	Takuatung.
Lakon.	Puket.
Jalar.	Trang.
Ranjeh.	Stul.
Rahman.	Perlie.
Kelantan.	Kedah.
Tringganu.	

In some of the provinces the works are very small and unimportant; but the total annual production is little short of 5,000 long tons, of a value of about £950,000, taking the price of tin at £190 per long ton.

Generally speaking, all the mining is in the hands of Chinese, the labour is Chinese, and the smelting is done locally by Chinese methods. The only exceptions to these generalisations are that one British and one Dutch company are working in Kedah, an American company is making a small commencement in Bangtaphan, and a British smelting company is establishing an ore-buying agency in Puket. The number of Siamese and Malays engaged in tin-mining is very small.

There is an enormous field for the expansion of the tin-mining industry in the Siamese possessions in the Malay Peninsula ; and considerable activity in prospecting on the part of European capitalists has lately been shown.

At present, Puket Island (on the West Coast) is the most important tin-mining centre in all the Siamese States ; but Kedah, Takuapar, and Renong (also on the West Coast) have a considerable mining industry. On the East Coast, Lakon Sri, Tammarat, and Jalar (Port Patani) are the chief centres. The most promising districts for future developments are in Kedah, Rahman, Jalar, Takuatung, and Renong.

TIN DEPOSITS OF BRITISH BURMA.

*Mr. T. W. Hughes-Hughes, of the Geological Survey of India, writing on "Tin Mining in Mergui district at Kahan," states there is

* "Geological Survey of India," Vol. XXII., Part 3, 1889.

no vein-bearing ore, but a bed of felspar of from 4 to 6 feet in thickness, scattered through which were specks of black tin in very irregular and meagre amount.

At Tharupîn, 32 miles from Mergui, and situated, like Kahan, on the right bank of the great Tenasserim, there is a fair chance of meeting stanniferous deposits.

Near Bôkpyin there are some stream works, and tin ore exists here in sufficient quantities to pay for extraction. The ore bed in the cuttings varied between 5 and 6 feet in thickness, and was overlaid by about 10 feet of top soil. The mines about here are all owned by Chinese and Siamese. At Tônbyan tin lode stone was formerly worked.

At Thabawleik a cutting gave the following measurements :—Top soil 6 to 10 feet, then a strong pebble and boulder bed of slate and sedimentary rocks with highly charged stanniferous clay 8 feet below. Quartz fragments are rarer in the pebble bed here than at Taiping, Renông, and Bôkpyin.

The mining operations are carried on in the ordinary way. About 200 Chinese and Siamese are employed in the Baichuni mines. Here the ore bed is 6 to 8 feet thick, and fairly rich ; the whole district is capable of extensive development.

Karathuri : The ore beds here vary from 8 to 12 feet in thickness of good paying character, and water is fairly abundant.

Coolies are paid 42 dols. per year for 360 working days, food free. At Chaungtanaung the stanniferous stratum is only 3 feet in thickness, and poor quality.

At Yamon the ore bed is 2 to 3 feet ; not much mining being carried on in these districts.

At Maliwan the ore is said to yield better than at Renông. An English company attempted some lode mining here in 1873, but the venture proved a complete failure.

Dr. Oldham says in 1855, "The principal source of the ore is the extensive deposits of stream tin."

Mr. Mark Frayar, in 1871, was struck with the wonderful extent of the distribution of stanniferous detritus.

The progress of mining in the Mergui district has in the past not answered the expectations of the Government, and Mr. Hughes advises liberal conditions of acquiring concessions, and assistance for prospecting and placing of ore.

Tin deposits occur on the watershed of the Khamaungthwe River, a northern tributary of the Great Tenasserim River, east of Tavoy. The following account is taken from the reports of Messrs. Gilfillan and Cox on this district :—

Location and Area.—The Southern portion of the property is situated about 30 miles inland from Tavoy, an important town located on the estuary of the river of the same name.

It embraces an area of about 350 square miles, being the watershed of the Kamongthway River and its numerous tributaries, and extends north at Myitta some 35 miles, where the two high ranges forming its Eastern and Western boundaries converge on the borders of Siam.

The Kamougthway unites with the River Bean at Myitta to form the fine waterway of the Great Tenasserim River, which, flowing East and then South, bending North again, flows into the sea near Mergui.

Physical Features.—Some of the higher peaks of the boundary range are over 4,000 feet high, but the general average is less; the foot-hills and higher spurs are about 3,000 feet, while the elevation of the valley is about 2,500 feet.

The Great Tenasserim River below Myitta is 500 feet wide, but if is not navigable except by small boats during the driest months, on account of its rapids.

The Kamougthway above Myitta widens out in places to over 300 feet, has frequent shallows and gravel beaches; but even during the driest part of the year it is several feet deep, with fine pools 8 to 14 feet deep.

Some of the tributaries are fairly large streams, with well-defined banks; but their tributaries again are in many cases mere streamlets, becoming dry, or a series of pools, during the driest months (March and April).

The valleys of these streamlets, when ascended towards their source in the foothills or intervening ridges, gradually become narrow and more gorge-like, so the readily available area for alluvial mining becomes diminished. There are some fine flats adjacent to the main streams.

During the rainy season (June to November) some 200 inches of rain falls; then the whole of the river system is flooded, and the lower lying grounds inundated. With the cessation of the rainfall this water gradually drains off, the streams rapidly diminish in volume, and the smaller ones become dry.

The general water level thus descends from its maximum height attained about October-November, to its minimum about the end of April.

Sluicing operations can consequently be carried on most readily at the sources of the streams, and on the higher gravels, during the rainy season.

Shaft-sinking and the removal of the stream and lower gravels, without dredgers or mechanical appliances, can be carried on most conveniently after the termination of the rains, the hydraulic mining operations gradually being advanced towards the main stream as the water drains away.

The gravel beaches of the main stream could be sluiced during the driest month.

Geology.—There are few rock exposures even in the bed of the streams, so geological examination is difficult, and sufficient data have not yet been obtained to complete a map or form definite conclusions. The Western boundary ridge consists of granite, which also outcrops in various parts of the concession. Where the telegraph line crosses the Western boundary the granite is overlaid by a series of highly inclined stratified rocks, while eastwards, about four miles north of Myitta, a newer and less inclined series of fissile slates has been noted.

Timber—The whole of the area is densely jungled with bamboo

and other tropical plants. Some fine timber, suitable for all mining purposes, grows in many parts, and can be cut on payment of a small fee for the more valuable kinds.

The Golden Stream District.

The Golden Stream, or Schwey Chaung proper, is a small tributary on the North bank of the Hindu Chaung proper, a stream which at the time of our visit was not of great importance, but which flows eastward, joining the Khamaongthway approximately one mile above the Myitta township.

The whole of the country in this neighbourhood is relatively flat, but small ridges occur dividing the different streams.

The Hindu Chaung itself, when we were on the ground, consisted of a series of water-holes with small streams connecting them, and the tributary streams are so flat that they were hardly flowing at all. During the rains, however, there can be no doubt that all these streams are of much greater importance, and a large volume of water flows through the valleys.

The whole of this area is covered with soil, below which there are deposits of a tough plastic clay of varying thickness, and underlying this there is a gravel wash in the valleys which generally crops at or below the level of the streams, so that it is only where the streams have cut banks that the gravel can be tested without sinking; but wherever these gravel exposures can be got at, tin stone in greater or less quantity can be obtained by panning, and, in many cases, gold can also be seen in the dishes after panning off.

It is, of course, impossible where the gravel can only be got at in such a way to form quantitative estimates of its metallic contents which could be absolutely depended upon, and all we can say is that we washed samples from a number of places, some of them miles apart, which showed prospects quite good enough for sluicing or dredging.

At the Golden Stream itself some clearing has been done, and a few shafts sunk through the clay until the gravel has been reached, and while we were on the ground we had some stripping done, and the first bed of the gravel sunk through so as to form some idea of its value.

At the particular spot where our tests were made there was an overburden of about eight feet of soil and clay, below which about three feet of coarse gravel carrying tin and gold occurs.

Below this, again, there is a finer water-worn wash in which the yield is much less than in the three-feet bed, but with the appliances available we were unable to get through this on account of the water, and consequently were unable to prove whether or no other coarse gravel deposits underlie this first one, or to determine whether and where any gutter exists.

In dredging, this finer gravel would be treated with that overlying it, and dredging would be the most convenient method of dealing with the deposits in this district, as there is no fall for sluicing. Panning results of the soil and clay overlying the gravel showed very small quantities

of tin and gold, but the material would be extremely difficult to handle mechanically either by dredge or sluice, and we think there is no doubt it would have to be removed either by hand or mechanical excavators before dredges were set to work.

As regards the value of gravel, we washed a section 4′ by 4′ by 3′

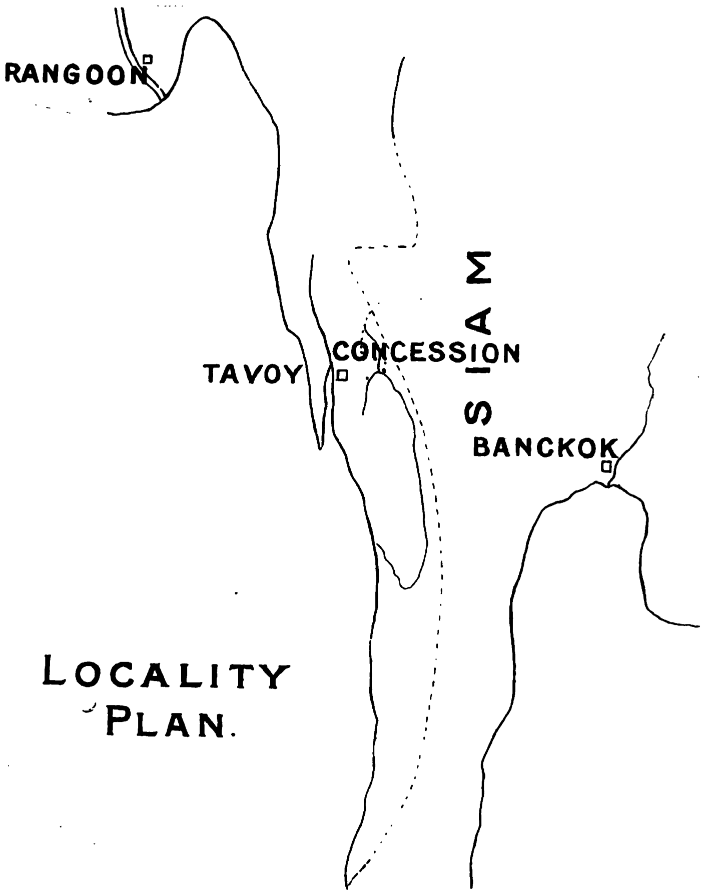


FIG. 14.—PLAN SHOWING TIN DEPOSITS OF BRITISH BURMA.

deep, which yielded 5·84 lbs. of concentrates = 3·28 lbs. per cubic yard, and this sample when assayed yielded :—

Gold	11 ozs. 7 dwts. 1 gr. per ton.
Silver . . .	1 „ 6 „ 22 „ „
Tin (metallic) 55 per cent.	

In the Hindu Chaung stream itself, wherever gravel is exposed, tin is found in the wash, but with much less gold than in the Golden Stream. We had samples panned from several places, and made one test of seven dishes which appeared about an average of what could be seen. These seven dishes = $1\frac{3}{4}$ cwts., yielded 4 ozs. of concentrates of 4·2 lbs. per cubic yard, assaying :—

Gold	18 dwts. 16 grs. per ton.
Silver	14 „ 5 „ „
Tin	67 per cent.,

or reduced as before to the 70 per cent. tin basis, 4·02 lbs. of concentrates containing 70 per cent. tin and 19 dwts. 11 grs. gold per ton. The value of these concentrates is £79 1*s.* 7*d.* per ton = 2*s.* 10*d.* per yard of gravel.

Labour.—During the first month the local inhabitants (Karens) were employed, and some of them worked remarkably well for 18 rupees per month, but in January most of them left, being unused to continuous work, and being desirous of attending to the cultivation of their plots of new ground. A few of them have continued to accompany me when prospecting, and are excellent men for that class of work or jungle clearing, but they decline to do shaft-sinking or earth-removal work. Some coastal Burmese were engaged, but as they could not get the food supply that they were used to, they left. Generally speaking, although some local labour may occasionally be obtained, still it cannot be relied on for continuous mining work. Two gangs of Indian coolies, Pathans and Keringues, were engaged, without adequate selection, by a labour agent in Rangoon, the rate of wages being 25 rupees per month for the former, and 20 for the latter. Some of these men worked well when under European supervision, doing as much work as many white miners would do under more favourable circumstances.

Climate.—The climate is tropical; the months of December and January were not unpleasant, and the nights were cold, with a dense fog. In February and March the weather was warmer and more trying, and before the break of the monsoon was specially so. In May the heavy rainfall commenced, which will last till November.

At Henzai Batin N. of Tavoy, a promising alluvial deposit containing crystals of cassiterite has recently been located by Mr. G. D. Ricketts.

* *The Khow Maung District.*—The property is located in Lower Burma, situated near the Maliwun River, which, being navigable, offers easy access to the sea at Victoria Point, a distance of about twenty miles.

Mr. A. D. Snow writes as follows :—"I have found what appears to be one of the most extraordinary combinations of lode and alluvial tin that have been discovered in any part of the tin-producing East Indies. Not only have we the most important factor for successful tin mining—a big tin lode and rich alluvial deposit—but we have also natural facilities, such as water power, timber, and a good climate to

* "Mining Journal," Oct. 13th, 1906.

assure cheap production. Tin has been known to exist in the Maliwun district for many years.

"The area of the Khow Maung tin-bearing zone is so extensive that one hardly knows where to begin, and it is not likely that even the most practised and industrious prospector could at once strike the richest part of the tin ore on the Khow Maung Hills. In my first adit at Centre Hill, where I cut the formation at right angles over a distance of 268 ft., I found the surface tin quartz strata to continue downward, and to carry in value about the same per cent. of tin as the same strata contained on the surface. Although I could not find in the length of this adit values high enough to justify a favourable report, I have made this valuable discovery—that every one of the quartz strata that showed on the surface has been cut underground by our adit, and is still continuing downward; thus we have a fair right to suppose that all the tin-bearing rock of the Khow Maung zone will be found to be as rich under as on the surface."

* Stanniferous Deposits in French Indo-China.

These remarkable deposits occur in the valley of the Nam-Patain, a small stream which runs into the Hinbun, itself a tributary of the Mekong. This valley lies in what the author terms the Middle French Laos, the country which extends along the left bank of the great river just named, between Annam and Siam, and north-east of Cambodia.

The geological structure of the intermediate neighbourhood, in so far as it can be guessed at, under a covering of barely penetrable bush and thick forest, is sufficiently simple. We have here a syncline of more or less argillaceous pale Tertiary grits, between two high serrated walls of limestone which shoots up into crags, and pinnacles, and peaks, that show no easily apparent trace of bedding. No eruptive rocks have been discovered, up to the present, in the valley or in the surrounding district; but there are quartz-veins in the grits, which undoubtedly are in some way connected with the stanniferous deposits.

On the slopes of the foot-hills are considerable quantities of limonite, occasionally manganiferous to a high degree, which appear to belong to the uppermost stratum of the grits. These are but fragmentary patches, all that has been left by erosion, of the deposit as it was originally laid down, but it is in them that the tin-ore is found, in a finely-divided state. Four such deposits are known, and there may be others: they are dispersed along the right bank of the stream, but limonite has been also observed at two points on the left bank.

The only stanniferous ore-body that has been properly studied so far, lies a little way up stream from the village of Puntiu; but, as all the others have precisely the same external characteristics, it may perhaps be regarded as typical. The limonite has been carved up by erosion into isolated blocks immersed in sandy ore: the tin-ore occurs

* "Gisements stannifères au Laos français." By L. Gascuel. Annales des Mines, 1905, series 10, vol. viii., pages 321–331.

throughout both the blocks and the sand, in the biggest fragments as in the smallest particles. Nothing reveals its presence to the eye, except where an especially rich morsel occurs (assaying, for instance, more than 10 per cent.). The cassiterite is, indeed, in so fine a state of division that, with crushing and washing, only a very small proportion of it can be retained : most of it is carried off in the sluicing. The ore is of a red-brick colour, more or less tinged with brown : the outer surface of the bigger blocks is brown, and where manganese predominates the colour is darker still. Antimony and bismuth also occur in association with the limonite, but no sulphur. The Puntiu deposit has been worked in a nonchalant and primitive fashion by the natives, in the intervals left by the rice-sowing and the rice-harvest, by means of roughly circular shallow pits. Smelted in an equally primitive fashion, the ingots of tin are purchased by Chinese merchants at Pak Hinbun, and sent off to Bangkok. However, it is thanks to this mineral industry, such as it is, that the natives are enabled to pay regularly their taxes, even in the years of drought ; as to working on a large scale, by European methods, the prospects do not seem hopeful at present. Opencast working would not be difficult, but the ores are too poor, they occur too far away from any industrial and commercial centre, and the means of access are still the reverse of easy. By the quickest route, it takes twenty to twenty-five days to reach the site of the deposits from Saigon, and that by a mere track. For goods, the Mekong river furnishes the only possible (but unreliable) approach.

CHAPTER V.

ALLUVIAL TIN MINING.

STREAM tin is harder to separate from the gravel than gold on account of its somewhat low specific gravity. There are various methods employed, the one most in use being the separation of the tin-ore by means of the sluice box, which slightly differs from the one used in gold mining. A fair stream of water is always necessary to effect good results. The two forms of sluicing may be classified as box-sluices and ground-sluices. In the former the gravels are lifted and placed in the sluice-box by hand, whilst in the latter the gravel is washed into them by water; this method can only be used when natural facilities are suitable. The length of the sluice necessarily varies with the quality and quantity of the gravel to be treated, and the fineness of the tin to be saved. There must also be a complete disintegration of the tin-bearing gravels. The grade best suited to the particular gravel to be treated must be determined by actual experiment.

A sluice-box commonly in use is about 16 feet long by 24 inches wide at the upper end, and 22 inches wide at the lower end. Seven of these boxes would make the tail-race a total length of 150 feet.

The Hopper-box, 8 feet long and 4 feet wide at the upper end, and 22 inches wide at the lower end, is fitted with a perforated iron plate 4 feet at the upper end, or a gridiron of steel or iron bars; and it is upon this that the first material is placed, and the large stones removed by a fork. In the sluice, men are posted at intervals with shovels, whose duty it is to push back the heavier ore against the water, allowing the lighter material to flow away; and it is to a great extent upon the efficient working of these men that the amount of tin saved or lost depends.

Within the first few feet about 80% of the tin-ore is saved, and it is necessary, where the quantity of tin-ore to be treated is very large, to place several men close together in the race. After this point, one or two men walking up and down the race and stirring any masses that may have collected at any particular point will be found sufficient. The exact point at which it will not pay to further handle the ore can be easily determined by direct experiment; this is largely dependent upon the quality and quantity of the alluvial wash to be treated and the size of the grains of tin-ore.

A mechanical rake has been substituted in the tail-race by way of experiment, but it was found that the loss of tin was greater by this

BOX SLUICING FOR TIN, NEW SOUTH WALES.

method, and did not compensate for the saving of labour. After the sluice is washed down the concentrates must be further cleansed by hand ; and this is better accomplished in a separate box about 5 feet long by 3 feet wide and 8 inches deep, with a small stream of water about $\frac{3}{4}$-inch deep. The larger pieces of foreign matter can be picked out by hand.

These impurities consist mainly of some form of iron, small pieces of quartz, and other débris. Although this may seem a very simple operation, the author, who has had considerable experience in the treatment of alluvial tin gravels, has found that some men will never be really good sluicers, for the whole operation requires most careful watching to see that the tin is not lost. It is quite impossible to save the whole of the tin, but the loss should not exceed from 2% to 5% of the tin-ore saved. All clay should be eliminated as far as possible, as it has a tendency to ball and pick up particles of tin in its passage down the sluice.

By means of ground sluicing a far larger amount of alluvial wash can be treated. Roughly speaking, about six times more water is required than is necessary for box-sluicing.

The method is to have a small stream of water running over the top of the face, and the larger quantity introduced into the tail-race at a lower level. As all the overburden as well as the wash goes into the tail-race, it is necessary to have this as long as possible, with ripples placed in it at intervals. This particular form of sluicing can be used with advantage in a country where the seasons are extreme, and the water supply excessive at some periods of the year and non-existent at others, when the sun would destroy the wooden sluice-boxes.

The precautions to guard against failure are to be quite certain that there is sufficient fall in the tail-race, and an adequate space for the disposal of the tailings. The sluice must also be of the dimensions necessary for the proper treatment of the material and the saving of the tin-ore. It is impossible to fix any exact size for the sluice and the fall, as this depends entirely on local conditions.

The length of the tail-race depends on the cost of construction and maintenance, the race being increased in length according to the returns.

Where, owing to physical conditions, the tail-race cannot be made of sufficient length, its tin-saving capacity may be increased by the use of drops in the race and by previously removing the coarser material. A double sluice is sometimes used, which enables one race to be in use whilst the other one is being cleaned up.

The following is the table given in *Hydraulic Mining*, by Captain C. C. Longridge, p. 81, on "The Duty of Water" :—

"The volume of water is variously measured in sluice-heads, cubic feet, or miner's-inches. Its moving power is proportionate to the volume or weight of the flow, multiplied by the square of the velocity, which in turn is proportional to the square foot of the gradient. One cubic foot of water will weigh 62·5 lbs., and if it moves at 10 feet per

second will have a momentum of 625 lbs. The weight of a cubic foot of sand is 100 lbs.

"Supposing, therefore, that a cubic foot of mixed water and sand, consisting of two-thirds water and one-third sand, is flowing through the sluice, the weight would be roughly 75 lbs., and the momentum at 10 feet per second velocity would be 750 lbs. Thus the density of the current and its ability to float stones would be increased by one-fifth. The quantity of water in sluice-heads, multiplied by a fall in inches in a 12 feet box, gives the number of cubic yards sluiced per hour."

Example :—

Number of Sluice Heads.	Grade in Inches per 12 feet box.	Number of Cubic Yards Sluiced per Hour.
10 heads - - -	6 inches - - -	60 cubic yards.
12 " - - -	7 " - - -	84 " "

Conversely, the number of cubic yards required to be sluiced per hour, divided by the fall of the box in inches, gives the number of sluice-heads (cubic feet per second) needed for the purpose.

EXAMPLES.

Showing the number of sluice-heads needed for sluicing one cubic yard per hour, in sluices of various grades :—

Grades.								Number of Sluice Heads required.
3	inch per	12 feet	box	or 1	in	48·00	- -	·333
4	"	"	"	— 1	"	36·00	- -	·250
5	"	"	"	— 1	"	28·00	- -	·200
6	"	"	"	— 1	"	24·00	- -	·166
7	"	"	"	— 1	"	20·57	- -	·142
8	"	"	"	— 1	"	18·00	- -	·125
9	"	"	"	— 1	"	16·00	- -	·111
10	"	"	"	— 1	"	14·40	- -	·100
11	"	"	"	— 1	"	13·09	- -	·090
12	"	"	"	— 1	"	12·00	- -	·083

The nature of the material naturally affects the above results. Material of high specific gravity, mixed with large quantities of irregular stones, decreases the quantity sluiced; whereas material of low specific gravity, with well-rounded stones, increases the amount. Alluvial, in fact, is more easily sluiced when it contains a fair proportion of well-rounded stones, say, from 4 to 8 inches diameter, since the stones keep the fine and heavier material from settling on the bottom of the sluice. Fine heavy wash is the most difficult material to sluice.

GROUND SLUICING FOR TIN, TASMANIA.

THE MOVING POWER OF WATER.

Assuming the amount of available water and the character of the material to be known, the strength of the current required to sluice the material has to be estimated, as on this depend the grade and dimensions of the sluice. In this estimation reference may be made to the following table, which shows the moving power of water in smooth, straight sluices, without riffles:—

TABLE I.

16 feet per minute	- -	begins to wear away fine clay.
30 „ „	- -	just lifts fine sand.
39 „ „	- -	carries sand as coarse as linseed.
45 „ „	- -	moves fine sand.
120 „ „	- -	„ pebbles of inch diameter.
200 „ „	- -	„ „ of egg size.
320 „ „	- -	„ stones of 3 to 4 inch diameter.
400 „ „	- -	„ boulders of 6 to 8 inch diameter.
600 „ „	- -	„ boulders of 12 to 18 inch diameter.

Reference to tables of this description, or, better still, to actual experience, will enable the engineer to select a rate of flow best suited to the material.

CALCULATING A GRADE.

When the required velocity of the current has been determined, the necessary grade for the sluice may be calculated by the following formula:—

$$b = \frac{V^2 \times P}{2\,A} \times C$$

Where b = Fall in feet per mile, which may be reduced to inches per 12 feet box, by multiplying with ·027; or to inches per rod (16 feet) by multiplying by ·036.

V = Velocity in feet per second.

P = Wet perimeter of sluice in feet.

A = Area in square feet, filled by the water and dirt.

C = Variable co-efficient, depending on the frictional character of the material and of the sluice-paving, and varying from 6 for light gravel, to 8 for boulders and heavy clay.

Example:—What grade in feet per mile must be given to a sluice 3 feet wide and 6 inches deep, to give a velocity of 320 feet per minute —*i.e.*, 5·3 feet per second, the gravel being fairly light?

$$G = \frac{(5{\cdot}3)^2 \times (3 + {\cdot}5 + {\cdot}5)}{2 \times 3 \times {\cdot}5} C = 37{\cdot}68\ C$$

Taking C in this case as 6·5, the fall per mile will be, roughly, 245 feet; or, multiplying by ·027, the grade per 12 foot box will be 6·6 inches.

It may be noted that a lengthy course of measurements at Kumara, the largest hydraulic sluicing field in New Zealand, has shown that with ordinary alluvial, sluiced in boxes, paved with wood blocks, the number of cubic yards of material required to be sluiced per hour, divided by the number of sluice-heads of water used, will give the required fall per 12 foot box.

Practically all the tin mining in the Malay Peninsula is carried on by the Chinese—very often in the case of alluvial mining without European supervision. The Malays are only engaged in a small way on the easily won surface alluvial; they also supply the timber and firewood necessary for mining operations on contract.

Surface Alluvial is generally exploited by a system known as "lampan," or surface, working. Several small channels are cut in a hillside, down which the washdirt is allowed to run into a main channel, where it is collected, and the tin washed up in an inclined sluice-box of a type which will be described later. Where water can be brought round easily, continuous working is carried on; otherwise it is necessary to wait for rain, which is stored in pits at the top of the workings. This is the method practised, mostly on a small scale, by the Malays, who never engage in anything like deep alluvial mining.

A good example of working this form of deposit is to be found on the property of the Leh Chin Mining Company, Limited, of Dublin, at Changkat Pari, Ipoh. This company has paid dividends varying from 5 to 15 per cent. uninterruptedly since its formation in 1891, and is still working at a profit. The mine is 277 acres in extent, and the system pursued by the company is leasing for short terms to Chinese. As fast as the ground in one place shows signs of exhaustion the coolies move a little further on. The outfit required for a gang of coolies consists simply of hoes, rakes, baskets, and a sluice box. The "changkols," or hoes, are of two kinds, long and short-handled. The latter have handles 5 feet long and are for breaking down the washdirt *in situ*. The handles of the former are 9 feet in length, and these hoes are for keeping the tin alluvial in motion whilst in the sluice box. The blade of the hoe is of wrought iron, and is made locally, costing about 50 c. (1*s*. 1¾*d*.). It is inclined inwards, *i.e.*, towards the holder at an angle of about 60°. For breaking ground its dimensions are: length, 1 foot; width, 6 inches; and for the sluice box it is 1 foot 3 inches long and 9 inches wide. The "ki-tsai," or wicker baskets for carrying the washdirt from the open works to the sluice box, are flat and of varying sizes, but 1 foot 6 inches long and 1 foot 3 inches extreme width in the middle are sizes commonly seen. They are carried across the shoulders on a yoke pole known as the "kandur" stick, about 4 feet long, the coolie balancing himself whilst carrying a heavy load on each side in an extraordinary manner. At first sight it would appear that this primitive method of transport would be both wasteful and inefficient. Experience in the Straits has, however, shown

HYDRAULIC SLUICING FOR TIN, BROTHER'S HOME No. 1 TASMANIA.

that European methods, whether by tramroads or otherwise, cannot compete with the coolies and their baskets for economy in working alluvial. From actual personal observation, it has been noted that a coolie will carry a load of 80 katis (104 lbs.) a distance of 50 feet to the sluice box, returning the same distance to the working face, in one minute. Coolies carrying baskets work 6 hours a day, in spells of 3 hours at a time. Deducting one-eighth, probably a good deal in excess of the actual period lost, at any rate with coolies working on contract, a coolie will carry 15 tons per day this distance. At the average rate of wages of 40 c. (10½*d.*) per day, this works out at 0·025 c. (¾*d.*) per ton.

Sluice Box.—For surface working a small sluice box ("lanchut ketchil") is used for washing the tin dirt, in contradistinction to the large sluice box ("lanchut besar"), employed in the case of deeper workings. The box is shaped something like a coffin, widening out in the centre, and narrowing again towards the bottom. It is inclined from the top downwards about 1 in 10, and has these dimensions, viz.:—

Length, 9 feet.
Width at top, 1 foot.
„ bottom, 1 foot 3 inches.
Extreme width, 2 feet 6 inches.

Water and washdirt are let into the box together through a hole 6 inches wide at the side of the box, and 1 foot from the top it. At the widest part of the box, which is situated 3 feet from the top, there is a ridge 3 or 4 inches high, over which the coolie, who is manipulating the tin ore, allows the mixed water and ore to escape in a small stream. The amount of each he regulates with a long-handled hoe and with his foot in a very expert manner. The art of doing this is only learnt after considerable practice, and being besides very hard work—for he must not stop for much rest whilst ore is in the box—the coolie doing this part will, by mutual consent, get rather more pay, say a few cents per pikul, than the rest of the gang. If the washdirt contain much clay it has to be puddled in a shallow rectangular pit at one side of the sluice box before being washed in it. The puddling is done with short-handled hoes. The tin ore is concentrated simply by being pushed up and down the bottom 6 feet of the sluice box with the long hoe, the action of the water leaving the clean tin at the top. As the coolies work three hours at a time, the box is cleaned up before changing shifts, except in the case of exceptionally rich ore, when it may be cleaned up twice in a shift. One coolie is employed in picking out the stones from the washdirt by hand, and with a rake. The latter, being of the ordinary kind, needs no description. Another coolie stands at the bottom of the sluice box with a short hoe, keeping the tail-race clear of the "amang," or gangue, washed down, and seeing that no tin escapes with it. Thus, if puddling be necessary, four men are required to work a small sluice box, but if not, then three men only. With a sluice box as described, 50 cubic yards (or say, roughly, 100 tons) of tin alluvial can be washed in six hours if the ground be fairly loose. The loss of

tin is not nearly so great as might be imagined, and, except with very rich ore, or careless washing, may be put down as not exceeding 3 per cent. An assay of a fairly rich sample of tailings from the Changkat Pari Mine, kindly made by Mr. Benedict Kitto, showed 1·7 per cent. of metallic tin, but, with the present system of working, the bulk of tailings would not run so high. The tin may be said to be saved rather by the expertness of the washer than by any particularly advantageous feature which this form of sluice box possesses. It is not often that it pays to rewash tailings. The Straits Trading Company, Limited, sell the tailings from the sluice boxes at the Ipoh works at 40 c. per pikul (= 14*s.* 10*d.* per ton), but in this case they are from the reconcentration of badly washed ore, and not from direct treatment of washdirt.

Working of Shallow Alluvials and Deep Leads.—The working of shallow alluvials and of deep leads may be considered conjointly, for the open cast system pursued is in each case the same. The overburden is stripped by a class of men known as "nai-chiang" coolies, so called because they are paid for this work at a fixed rate per "chiang." The latter has been fixed by the Chinese Protectorate at 30 feet long × 30 feet wide × 1½ feet deep = 50 cubic yards. The average price in Kinta is $4·00 to $7·00 (8*s.* 10*d.* to 15*s.* 5½*d.*) per "chiang," according to the distance the overburden has to be removed behind the working face. This is equivalent to 8 c. to 14 c. (2*d.* to 3¾*d.*) per cubic yard. The men working underground, or in the open mine, breaking down washdirt, or washing the same, may be of two classes: either "kung-si-kung" (so called from the word "kung," meaning a day's work), working on day's pay at fixed wages, in fact what are called in Cornwall "owner's account." The men in this case is the "thauke" or advancer, who may or may not be the actual owner of the mine guarantees their pay, whether the mine prove profitable or not); or "co-operative coolies," working in "kongsis," or gangs, in number from 20 men upwards. The remuneration of these latter depends upon the amount of clean tin ore produced, being in short a modified form of tribute with the advancer, who, if not the actual owner of the mine, has his own separate arrangement with the latter.

The "karang," or tin-bearing washdirt, is chiefly crystalline quartz, with some felspar; whilst the "kong," or bed-rock, is either granite or limestone.

Pumping.—Where water is encountered in any considerable quantity, it is raised by a "kin-cher," substantially the same as the old Californian wooden pump described and illustrated in Warnford Lock's *Practical Gold Mining*, p. 188. It is of similar construction to the pumps used in China and Japan for irrigating the padi fields, and consists of an endless chain of wooden slats, revolving round similar slats fixed on a wooden rod, and actuated by small wheels at the top and bottom of the same. The length of rod and chain varies, of course, with the depth from which water has to be raised.

At Saiak Tin Mine, near Batu Gajah, Kinta, there is a pump raising 75 feet in one lift, and this may be taken as about the maximum capacity. The angle of inclination is usually about 30°. The wheels

have eight spokes, each 1 foot long × 2 inches wide × 2 inches thick. The slats are 9 × 3 × $1\frac{1}{4}$ inch. The motive power of the pump is supplied at shallow depths by coolies working a treadle at the top. The barrel of the treadle is 6 inches diameter, and the spokes of the same on which the coolies tread are 9 inches long and 6 inches in diameter. With greater depths, where water power is available, small overshot wheels are used, 4 feet 6 inches diameter, and 3 feet breast, as much as one-eighth of the whole wheel being continually under water.

Chinese System of Mining.—Where the overburden is considered too deep to be removed by an open cast working, shafts are sunk, and the washdirt removed from them. If the ground will stand, in stiff clay for example, they are made circular, and are 3 feet diameter. In running ground they are 3 feet square, and are timbered with 1 inch laths. One mine will have twelve or more of such shafts, laid out in straight lines, and at right angles to one another. They are 18 to 20 feet apart. The shafts communicate with one another underground by a series of drives. Average size of drive at commencement of extraction of washdirt 4 × 3 feet. These will be continued in width and depth until the deposit of washdirt is worked out. The roof of the drive is supported at intervals of 3 to 4 feet by single props, 4 to 6 inches diameter. These have semi-oval slabs at top and bottom, the flat side in each case being nearest to the ground.

If there be only a little water in the workings it is baled out with the ubiquitous kerosene tin. Otherwise the workings are so arranged as to drain into one central sump, from which the water is pumped up through iron pipes 4 or 5 inches diameter. A centrifugal pump is then placed in the sump, and is worked by steam. The washdirt, if stiff clay, is raised in the wicker baskets already described. When too soft for these, kerosene tins are used. The ordinary load is 1 pikul at a time. A rough windlass is used for hoisting, such as is commonly seen with prospecting shaft. The barrel is 6 inches diameter, and is bound with hoop iron at both ends. According to the depths of the workings, the windlass is either single or double handled. The handles are simply pieces of bent stick dovetailed into the windlass barrel.

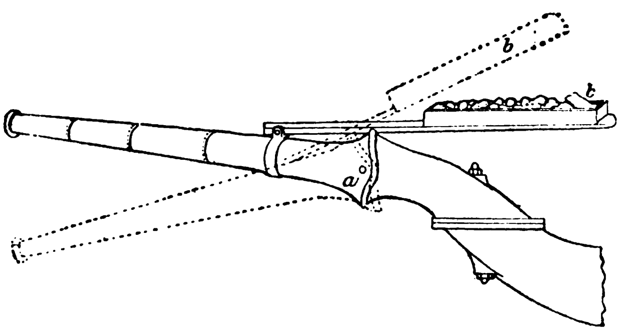


FIG. 15.—HYDRAULIC GIANT OR MONITOR.
Showing swivel connections (*a*) with the supply pipe, and counterweight (*b*), to facilitate the directing of the giant.

Where it is possible to use the hydraulic monitor its services should always be taken advantage of. This monitor or giant is used for breaking down the ground by cutting a piece away at the bottom of the face, which causes the upper part to collapse.

In breaking ground great care must be taken not to bring down too large a quantity at a time, which adds to the cost of removing, and might possibly injure the monitor and men at work. Fig. 14 gives a drawing of a monitor with the balance arranged so that it is possible for one man to work it in any direction without assistance.

Hydraulic elevators have been used with success in places where no other means were available. To work the elevator successfully there must be a sufficient volume and pressure of water, and the alluvial wash operated on must not contain too many large stones.

The size of the elevator to be employed can be determined by calculation before erection.

The following table is the actual result obtained from a mine in New Zealand:—

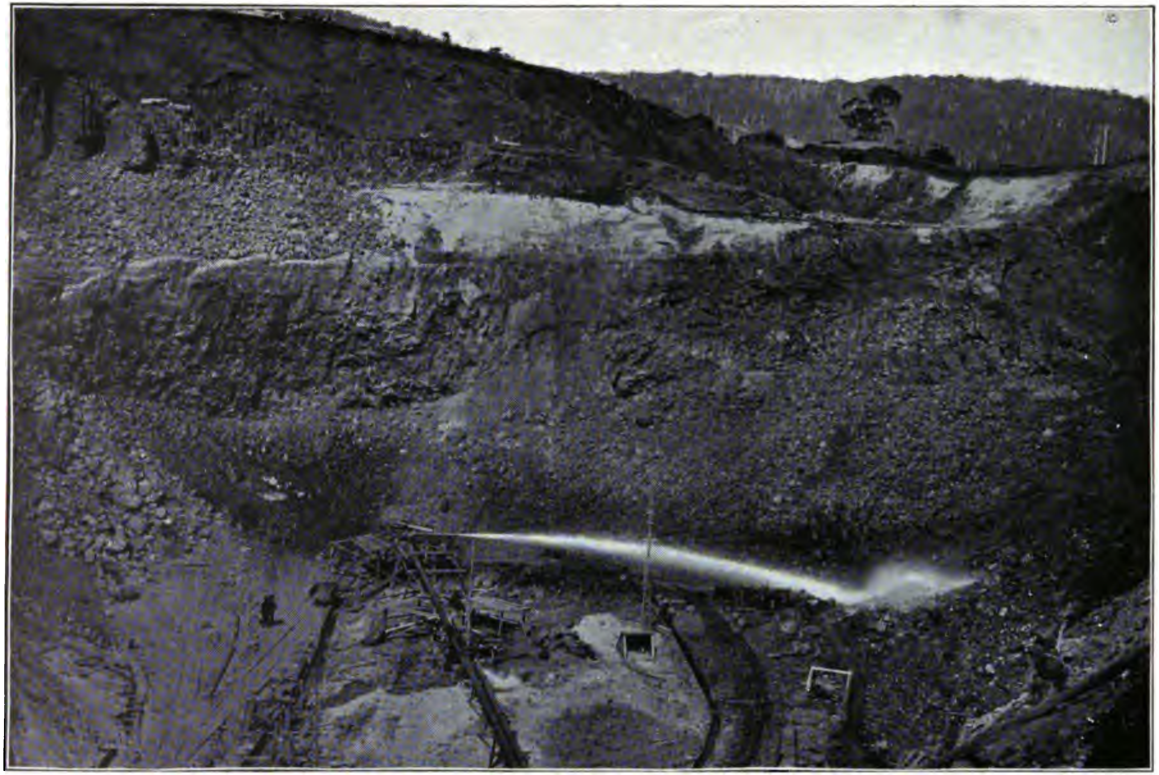
No. of Elevator.	No. of Hours Sluicing.	No. of Cubic Yards Sluiced.	Height Material is Lifted.	Head of Water on Elevator Jet.	Diameter of Jet.	Diameter of Liner on Elevator Pipe.	No. of Sluice Heads Used for Lifting.	No. of Sluice Heads Used for Sluicing.	No. of Cubic Yards Lifted per Hour.
			Feet.	Feet.	Ins.	Ins.			
No. 1	2179·5	58,107·9	62·5	400·5	$3\frac{1}{4}$	$7\frac{1}{2}$	10	8·75	26·66
No. 2	1816·5	60,550·0	63·5	408·0	$3\frac{1}{4}$	$7\frac{1}{2}$	12·5	11·25	33·30
No. 2a	1295·5	43,183·4	63·5	408·0	$3\frac{1}{4}$	$7\frac{1}{2}$	12·5	7·5	16·66
No. 2b	”		42·0	351·0	$2\frac{5}{8}$	$7\frac{1}{2}$	7·5		

Longridge, "Hydraulic Mining," p. 54.

The following account is given by Frank Owen of the Hydraulic Mining in the Malay Peninsula:—

"There are two alluvial mines in Perak worked by hydraulicing: The Bruseh Mine in the Batang Padang district, and the Gopeng Mine in the Kinta district.

"The Bruseh Mine hold a concession of 1,000 acres, of which 600 are estimated as payable as tin-bearing ground. The mine consists of a hillside 700 to 800 feet high, and before it was taken up by the present owners it had been worked by Malays by ground sluicing for 40 years. The ground is tin-bearing from surface down to a depth of 20 feet, with an average yield of 2 to 5 katis (2·6 to 6·5 lb.) of black tin per cubic yard. The water is brought round by a watercourse 5 miles, and down to the working face by 800 feet $\frac{1}{8}$-inch steel piping 8 inches diameter, in 6 feet lengths. The available head of water is 230 feet, giving about 100 lb. working pressure with a 2-inch nozzle. When there is a full pressure of water the monitor is capable of breaking down 300 cubic yards of washdirt in a working day of 20 hours. A good deal of this consists of hard lumps of clay difficult to break up, otherwise it is estimated



HYDRAULIC SLUICING, BRISEIS TIN MINE.

that 500 cubic yards of ground could be treated in the same time. The mine, when in full work, returns 200 to 300 pikuls (11·90 to 17·86 tons) of black tin monthly, with a produce of 68 per cent. metallic tin. As there is sufficient water to work a second monitor, which will shortly be erected, the output of the mine will be doubled without a proportionate increase in the working cost.

"Method of Working.—The washdirt is carried down the hillside from the working face to a series of sluices, in 120 feet of launders, 1 foot deep, beginning with a width of 1 foot and ending 2 feet 6 inches wide. There is a drop of 48 feet from the monitor to the launders, and the washdirt flows down a channel to the latter. The launders are lined at sides and bottom with corrugated iron to prevent them being worn out with rough stones, &c. The life of one of these launders, when lined with iron, is three years, whilst without it they only last one year. Bars of wood are nailed across the bottom, zig-zag fashion, to break up the hard lumps of clay. The launders are made in 12 feet lengths, and cost 21c. (5½*d.*) per foot run. At the bottom of the launders the washdirt has to pass through a grating of ¾ inch iron bars 2 inches apart. Any large stones are caught here and picked out from time to time; there is then a fall of 5 feet to the sluices, tending to further break up the clay lumps. There are 400 feet of wooden sluices 1 foot deep with varying widths, thus:—

"First 50 feet, 3 feet 6 inches wide.

"Next 300 feet, 2 feet wide (with riffle bars 3 inches wide and 2 inches thick, placed 1 foot apart).

"Last 50 feet, 4 feet wide.

"The sluices are constructed in lengths of 10 feet, having a drop of 6 inches between each length. Over 75 per cent. of the black tin saved is caught in the first 50 feet of sluices, where the washdirt is kept constantly moving with hoes, in the same way as in the ordinary sluice box. Stones are picked out with rakes.

"The riffle bars are removed when it is desired to clean out the tin from the middle part of the sluice. The ore from here and from the bottom 50 feet of the sluice is re-washed in the top box. A product of 50 per cent. metallic is obtained from the sluices; this is re-washed in a small sluice box of the kind previously described, and concentrated by hand jigging with sieves.

"The last 50 feet of the sluices have been widened to 4 feet with a view to re-washing all the tin there, and thus doing away with the sluice box. At Bruseh one man (a Malay) cleans 8 pikuls (9·52 cwt.) of black tin per diem. The tail race is 1½ miles long, 1 foot 6 inches wide, and 2 feet 6 inches deep, and is cleaned up once in six months, when a little tin is recovered. The total loss of tin is about 5 per cent. The system of working is to cut down ground with the monitor for 20 hours, and then to flush the sluices with clean water, and clean up the tin during the remaining four hours; the latter operation is of course done by day.

"The Gopeng Mine is situated near the town, from which it takes its name. The area of the concession is 500 acres, the average depth

of washdirt 12 feet, and the yield of same about 2 katis (2·6 lb.) of tin oxide per cubic yard. There is no overburden to be removed. There are 2½ miles of watercourse and 5 miles of ⅛-inch steel piping 12 to 13 inches diameter in 12 feet lengths, with telescopic joints. The monitor has a 2-inch nozzle. It is employed in cutting ground for 14 hours, the remaining 10 hours being for washing up the tin.

"The monitor works from 4 p.m. to 6 a.m., and washing up takes place from 6 a.m. to 4 p.m. The head of water available is 249 feet, giving a working pressure of about 108 lbs. The ground, being soft, is broken up by the monitor at the rate of 500 cubic yards in 14 hours. The system of washing is different to that at Bruseh. Here there are no sluices or riffles, but simply a long ditch in which 40 Malay women are stationed at intervals. They catch the tin dirt as it flows past them in a wooden dish called a 'dulang,' similar in shape and size to the South American gold-washing 'batea.' They are paid 40c. (10½*d.*) per day, and but very little tin, it is claimed, escapes in the tail race."

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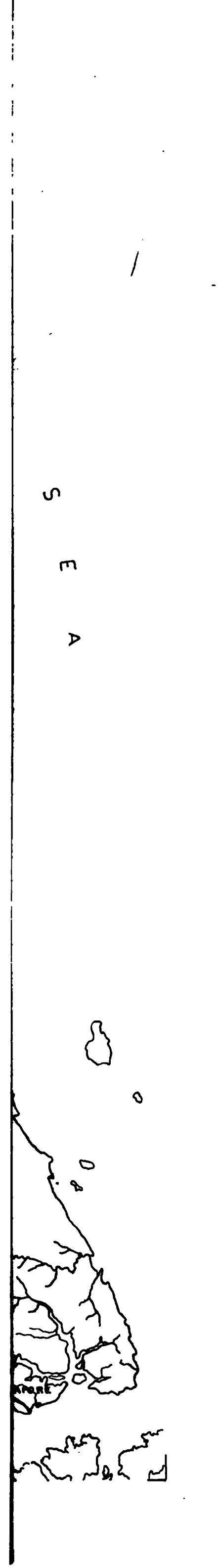


CHAPTER VI.

TIN LODE DEPOSITS IN THE MALAY PENINSULA.

THE PAHANG CORPORATION, LTD.—This company holds a government lease of 200 square miles situated about 40 miles by river from the port of Kuantan, in the Federated Malay State of Pahang.

The country has a gradual slope from the coast to the mountains about 40 miles inland where the mines are situated; the axes of these mountains are granite. The general geological features resemble the west of Cornwall, but the geology of this part of the Peninsula has been little studied. Mr. W. H. Derrick, in a paper read before the Institute of Mining and Metallurgy, gives the following particulars :—

"The lodes run approximately east and west, are from 50 to 2,000 feet apart, and range in thickness from 2 to 10 feet, producing from 1 to 15 per cent. of tin oxide to the ton. The lodes underlie both north and south, at angles ranging from 10° to 40° from the vertical; they have generally one well-defined wall, but seldom two. The granite is overlaid by varieties of clay schists, with the tin lodes running down right through the slate into the granite, a few isolated hills of calc-spar remain, although at one time this rock must have covered the slate, as the latter is everywhere seen intersected with veins of spar."

Mr. F. J. Stephens, in a paper read before the Institute of Mining and Metallurgy on the same mine, writes as follows :—

"The beds of the rivers are full of boulders and gravels consisting largely of granite and gneiss. In some cases the granite has become decomposed over considerable tracts, forming kaolin of a remarkably pure quality. This granite contains for the most part a large proportion of felspar, but very little mica.

"Tourmaline or schorl is rarely met with,

"On the Kuantan River, some miles below the tin mines of the Pahang Corporation, limestone occurs in great masses, white and greyish in colour, and lying unconformably on slates and schists; and calc-spar is found in great quantity along many of the hill-tops, again resting unconformably upon the steeply-inclined edges of the slates.

"Massive clay-slates, imperfectly jointed, and very rarely showing conformable cleavage, are met with, usually dipping at a high angle and

* Trans. of Inst. Min. and Met., Oct. 1898.

having a general N.E strike. These become schistose occasionally, mica entering largely into their composition. They are of various colours, but a dark blue tint predominates. Large areas of these rocks are broken up, presenting the appearance of compact breccias. Quartz does not enter largely into their composition, although the lodes in their barren parts seem to be composed entirely of quartz. Cross-courses appear very frequently in the Kuantan district; in fact. considerable disturbance must have occurred at some time, there being many dislocations of the rocks themselves.

"The geological structure at Sungei Lembing is so remarkably like that of certain parts of Cornwall that the disappearance of the main lodes in depth would be a matter of surprise; even had I not seen the lodes cutting the granite in the S. Kenau, I should have no hesitation in saying that they would continue through granite if it were encountered. Nor have I any doubt that it will be possible to follow these lodes in granite for considerable distances, seeing that in Cornwall similar fissure lodes have followed the granite for over 1,000 feet. The Sungei Lembing Lodes are exceptionally rich, they are of great width, and they carry over considerable parts of their course a high percentage of tin ore."

*The principal metals found in the lodes are tin, copper, iron, and arsenical pyrites, blende, and galena. Of these metals tin and copper only have been discovered in workable quantities; the latter usually carries from 25 to 30 oz. of silver to the ton, and appears to be quickly giving place in depth to tin.

The mines now being worked by the Pahang Corporation were, so report says, continuously worked by Malays and Chinese for more than 100 years, the large surface excavations made by them, some of which are 1,000 feet long, 200 feet wide, and 150 feet deep, testifying to this being a fact. The open-cast system was the only one adopted by the old miners, and as timber was seldom made use of to secure loose ground, the sides of their working were sloped or terraced to keep them from falling in. This, and not the thickness of the lodes, accounts in many instances for the great width of the old workings. Under native management (at least within recent years) the mines were not a financial success, owing apparently to want of capital, and, consequently, of proper machinery, as well as the native objection to doing anything in the shape of dead work, their mode of operation being to follow any payable ground from the surface down as far as they were able to without steam pumps and timber.

Explosives of any description were never made use of owing to a strange superstition firmly believed in by the Chinese, viz., that the use of explosives frightens away the metal in a mine. In consequence of this, any very hard ground could not be worked. The ore obtained was crushed by wooden stamps shod with iron and worked by small overshot and undershot water-wheels. The only dressing appliance used was a Long-tom, the tail losses from which were very heavy. These

* W. H. Derrick, op. cit.

tails were assayed, and found to contain as much as 7 per cent. of tin oxide. They are principally composed of coarse grains of tin and quartz adhering together, which only required finer crushing to allow the tin to be readily separated out.

For working the mines, the Pahang Corporation made use of Chinese, Javanese, Malay, and Tamil labour, Europeans being employed for supervision work only. With the exception of ore dressing, all work is let out on contract.

Stoping is paid for by the truck of 16 to 18 cwt., prices delivered at the battery ranging from 1*s.* 9*d.* to 6*s.* per ton, according to the nature of the ground stoped and the distance of the mine from the battery, which in some cases is as much as 2 miles, the mines being all connected with the batteries by tramroads.

Contractors pay for all tools and materials, dynamite, fuze, detonators, candles, &c., and put in timber as required.

If the quality of the ore delivered at the battery drops below a certain percentage (which is fixed at the time of letting the contract), the contractor receives nothing for such ore. This insures the Company against the delivery of waste. Each contractor's parcel of ore is stamped separately, and is constantly sampled and assayed as it passes through the mill.

Driving and sinking are let by the fathom, and prices range from £1 10*s.* to £4 for drives 7 feet by 5 feet; £2 10*s.* to £5 10*s.* for winzes 6 feet by 5 feet; £5 to £30 for shafts 12 feet by 4 feet, these dimensions being all clear of timber.

Contractors, as in stoping, pay for all stores and put in timber as required, the timber of course being supplied free by the Company. Drills are sharpened for contractors free. At one time this work was charged for, but it was found men wasted much time by using blunt tools rather than pay to have them re-sharpened.

The distances driven per month by a gang of six men working in 8-hour shifts vary from 10 to 40 feet according to the nature of the ground.

Shaft-sinking ranges from 10 to 20 feet per month in hard slate, when twelve men are employed working 6-hour shifts.

The Chinese miner makes good progress in moderate and soft ground, but is usually a poor miner in really hard rock, and on this account he cannot compete with white labour. If time alone was the sole consideration in mining this might be so; but when expense also is taken into consideration, it is far otherwise, a fact which is very apparent when one considers that white labour when employed on actual mining work is about ten times as expensive as native labour; in other words, a white man has to drive or sink ten times the distance done by a native in order to compete with him, whereas in any but hard ground his progress would probably not much exceed that of an ordinary skilled Chinese miner.

The average cost of mining, including cost of drives and winzes (but not permanent shafts), timber, hauling and pumping charges, and European supervision, is 5*s.* per ton.

The Pahang Corporation have a battery of 70 head of stamps. The stamps are of the usual Californian type, weigh 850 lb., and driven at a speed of 90 blows a minute, they crush about $2\frac{1}{4}$ tons per head per day. Vertical, high-pressure, non-condensing engines supply the motive power.

The dressing appliances first introduced were the usual concave and convex buddles from 12 feet to 25 feet in diameter, frames and tossing gear as seen on the dressing floors throughout Cornwall; but notwithstanding the cheap labour available for working these, they are gradually being replaced by more modern machinery and with the best of results.

Frue vanners with corrugated belts, size 4 feet by 12 feet, are found to answer well in treating the ore as it comes direct from the stamps without classification. Working thus on ores carrying a large percentage of pyrites, the tables give heads (containing 25 to 45 per cent. of tin oxide) sufficiently clean to go direct to the calciner without further handling, and with tails ranging from 3 to 5 lb. to the ton. Three tables are employed to treat the output from 10 heads of stamps. The heads from the vanners are much cleaner than those obtained from the buddles, and the introduction of vanners has resulted in a reduction of at least 50 per cent. in the quantity of raw concentrates returned to the calciners, and, consequently, is a corresponding saving in roasting charges.

For calcining, the ordinary reverberatory furnace is used; and with wood at 10*s.* per cord (128 cubic feet), cost of roasting, including labour, is 4*s.* per ton of concentrates treated.

Tin-dressing coolies cost 18*s.* per month. Native engine-drivers, carpenters, and blacksmiths £2 to £3 per month. Europeans for supervision work, £20 to £30 per month. The total dressing cost, which includes stamping, European supervision, native labour, stores, and roasting charges, is 5*s.* 6*d.* per ton of stone crushed.

The standard to which the oxide is dressed always exceeds 70 per cent. of metal, the impurities being oxide of iron, a little silica, and from $\frac{1}{16}$th to $\frac{1}{8}$th per cent. of copper.

The total battery losses range from 5 to 8 lb. to the ton.

Two pulverisers are employed grinding some 250 tons of coarse concentrates per month. One frue vanner is found sufficient for each pulveriser. Plain belt machines, belts 4 feet by 12 feet, are found to give good results with the fine ore from the pulverisers, returning a very clean head, and the tails not exceeding 6 lb. to the ton when working on concentrates running as high as 10 per cent. tin oxide to the ton.

A separate engine is employed for driving the vanners, and a high-level tank is used for the water supply for same, thus ensuring a regular speed and steady flow of water—two very essential points in the successful working of frue vanners.

Jiggers of the three-compartment type were tried at one of the mills, but did not give satisfactory results, and were consequently discarded.

The production of one ton of oxide, in which form the ore is sent from the mines, costs from £45 to £60, but it of course varies greatly owing to the variable percentage of oxide in the stone treated.

Output.	Stone Crushed Tons.	Black Tin.	Value.
1900–1 - -	26·822	555	46·707
1901–2 - -	22·763	662	—
1902–3 - -	25·150	523	43·159
1903–4 - -	27·770	452	32·063
1904–5 - -	24·655	472	33·995

Working costs are given as follows in the directors' report of the company up to 15th December, 1904 :—

Our total working costs, including expenditure on development and all charges, amount to $14·12 per ton of ore, as sent to the battery after sorting and rejection of waste.

Working costs amount to $12 79 cents per ton. The value of tin in the ore won from the mines averaged $15·96 per ton, thus showing a working profit of $1·84 per ton.

The average price obtained for our tin oxide was $809 per ton this year.

The mill crushed and treated 22,770 tons of ore, which produced 452½ tons of tin oxide, showing an average of 1·98%, as against 25·150 tons, producing 523 tons, averaging 2·08, of the previous year. In addition to the above, 7,600 tons were crushed and treated on account of the Pahang Kabang, Limited, making a total of 30,370 tons of 2,240 lbs. dealt with during the year, against 34,940 tons of the previous year.

Including European supervision, native labour, stores, repairs, and renewals to battery, dressing plant, furnaces, etc., these amount to $3·21 per ton.

For the journey up and down a distance of some 80 miles, the rate of carrying stores one way and tin the other is $11·76 per ton.

Pahang-Kabang, Ltd.

Output	Ore. Tons.	Black Tin. Tons.	Per Cent.
1904 - -	10,950	161	1·46
1903 - -	8,530	136½	1·60

Tin Lode Mining in Tringganu, Malay Peninsula.

The Malay State of Tringganu is on the east coast of the Malay Peninsula, and it is in the southern district of this state, known as the district of Kemaman, that the tin lodes worked are situated. Kemaman adjoins the Kuantan district of Pahang, to which it is geologically allied. The principal mine is known as the Bundi Tin Mine, situated about 40 miles to the north of the mines, worked by the Pahang Corporation, Ltd.

The Bundi Mine is held under concession from the Sultan of Tringganu. A royalty of 10 per cent. is paid on all tin ore raised. There are no other charges, whilst timber and water rights are covered by the concession. A microscopic examination of the granite rock at Bundi

shows that it may be classed as a fine-grained Biotite granite; the geology of this part of the peninsula has not been much studied, and the dense vegetation makes any extended examination very difficult.

The axis of the range of mountains to the west of Bundi is undoubtedly granite. The cap of the mountain consists of schists and slates resting on grits at an angle of about 33°, which again rests on granite dipping to the east at an angle of 42°. It is in a valley at the foot of this mountain that the Bundi mine is situated. The mountain rises about 1,500 feet above the surrounding country.

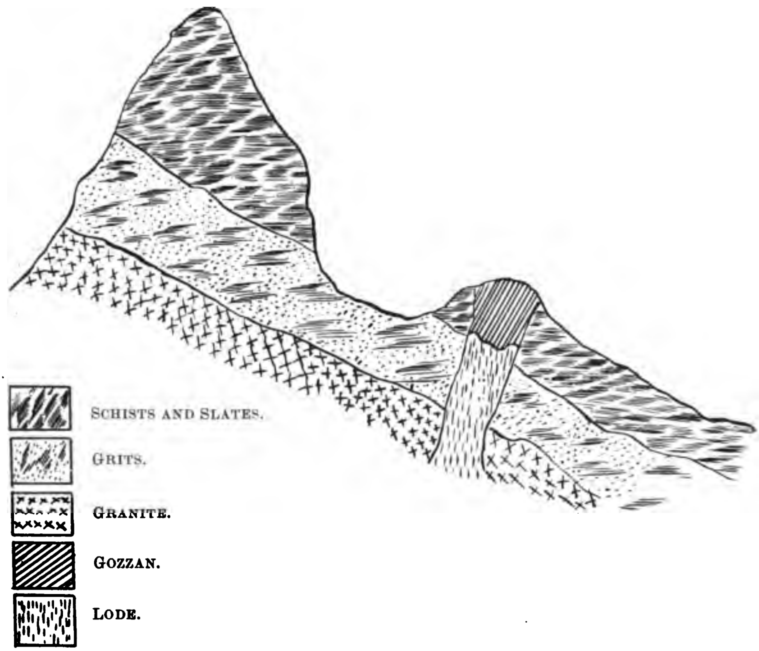


FIG. 16.—PROBABLE SECTION OF BUKITT BUNDI.

The junction of the granite and grits is very clearly defined on the south-west side of the mountain. Near the base of the mountain and in the valley lie a series of metamorphic schists and slates often micaceous and talcose, and sometimes graphitic in character. These sediments were considerably disturbed and metamorphosed by the granite, and at some time must have covered the granite bosses now visible on the surface. It is at the junction of the two rocks where the best tin ore is met with. Mr. Henwood mentions a similar feature in the Cornish mines where the best mines are situated on the granite margins, and the geological features of a large area about here closely compare with that of the west of Cornwall. Lodes near the granite bosses are generally richer in tin ore than those situated at a distance from them.

The schists and slates here are petrologically very like the killas of Cornwall. Some of the rock masses are of a dark grey appearance, owing to the amount of clear quartz present. A microscopic examination of the slate in the vicinity of the ore deposit near Glen Reef showed the characteristic well-formed crystals of cassiterite with sharp and rounded angles. These occur in association with axinite, the latter showing their characteristic wedge-shaped sections. Quartz occurs interstitially.

Intrusive basic dykes do not occur in the immediate neighbourhood of the mine, but are to be seen in some of the water-courses near.

The rocks and minerals associated with the tin lodes at Bundi are as follows :—

Rocks.	Minerals.	
Granite (Biotite)	Quartz	Iron Pyrites
	Felspar	Copper Pyrites
Porphyry (Eurite)	Tourmaline	Talc
Schists	Cassiterite	Chlorite
Slates	Hæmatite	Muscovite.
	Albite.	Topaz.
	Axinite.	Oxides of Iron.
	Biotite.	

The Bundi Lode traverses the country for miles, the outcrop forming quite a feature in the landscape. The strike of the lode is 15° E. of N., and it has a slight easterly underlay with an average surface width of 40 feet. Towards the south it has been subjected to a considerable amount of denudation, and the cap covered by clays and alluvial detritus. Towards the north it has a heavy cap of Gozzan, which near the surface is stained a dark red by the decomposition of the iron pyrites.

This gozzan is only stanniferous in parts ; a considerable portion was worked by the Chinese in an open cut. Some of the gozzans returned when milled from 3 to 5 per cent. of tin ore ; the stanniferous portion has now all disappeared.

The rich ore body at present worked at a point on the lode known as Glen Reef is in the schist country overlying the granite at a depth from the surface of about 100 feet. The granite is dipping to the south at an angle of 42°.

The ore body here has no well-defined walls, and the character of the ore is very varied ; the deposit lies between the granite and schist country, veins carrying the cassiterite penetrate into the enclosing rocks for some distance, and in the miner's sense may rightly be described as a contact deposit. The whole of the lode here is more or less decomposed. The decomposition of the granite has formed a pure kaolin, which carries some rich cassiterite in places.

The major portion of the lode consists of chloritic schist heavily charged (iron pyrites and cassiterite). A microscopic examination showed that the vein stone consisted of cassiterite crystals and chlorite; the latter occurs interstitially in small flake-like crystals, there being no

quartz. This ore deposit rests on the granite, which has a southerly dip of about 40 degrees. Intermixed with the schists occur boulders and veins of quartz ; calcspar is also present in small quantities.

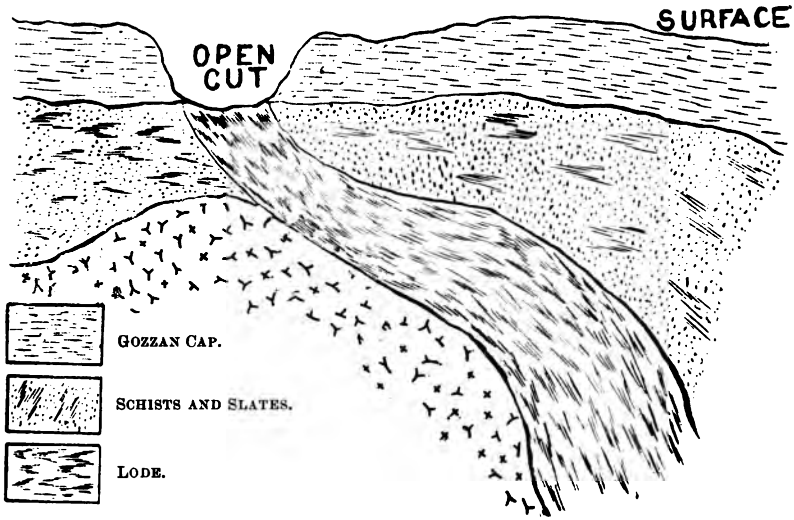


FIG. 17.—SECTION AT GLEN REEF.

At the time of my visit in April, 1904, the portion of the lode worked was 35 feet wide, and extended 200 feet to the south. The battery returns were over 10 per cent. A great deal of the cassiterite is of a fine crystalline character ; the lode narrows in width at the lower level, which is about 27 feet wide at this point. It will probably enter the granite at 200 to 250 feet in depth. A shaft known as Anderson's Shaft, about 700 feet due south of Glen Reef, has been sunk 210 feet west of the lode. A drive was started at the 205 foot level to cut the lode. At 130 feet in the drive a small bunch of tin ore was met with, and a winze sunk at this point to a depth of 35 feet has disclosed an ore body which is at present not well defined. The cassiterite here is fine and compact, and loses the crystalline appearance of the ore at Glen Reef. A microscopic examination of a specimen from this ore-body showed that the ore consisted of a ground mass of quartz and felspar, the cassiterite being more finely crystalline in character than the specimen examined from Glen Reef. This is probably a small body of ore, with no direct connection with the main lode. It resembles very closely an ore-body worked in the Ben Lomond district in Tasmania, and may better be called a massive impregnation rather than a defined lode.

The lode at Bundi constitutes one of the best defined and richest tin

lodes at present operating in the Malay Peninsula. Taking this lode in conjunction with the lodes at Sungei Lembing and other places in the Kuantan district, 40 miles to the south, and the district of Sunghie Ayam, 20 miles to the north, goes to prove that a large tin lode mining centre exists in this portion of the peninsula. In the distant future when the alluvial is worked out, the lodes must form the main deposits that will have to be depended on for the future tin supply. It must also be remembered that vast areas of this state, and in fact all over the Malay Peninsula (now covered with dense jungle and very difficult of access), have yet to be explored.

The mine is well equipped with pumping and winding plant. The rock drills are worked by Malays and Javanese most successfully. The out-put of this mine for 1906 was about 20 tons of black tin per month.

The mine gives employment to 500 men in all, 120 Javanese and 240 Chinese, who do most of the mining and surface work, and 200 Malays who are largely employed in cutting timber for fire wood on contract at $3 per cord, delivered at the mine.

The rate of wages does not materially differ here from the rest of the peninsula :

Chinese carpenters - - - - - -	$1 a day.
Chinese miners - - - - - -	70 cents a day.
Chinese contract coolies - - - -	50 ditto
Engine drivers - - - - - -	70 ditto
Battery and dressing-sheds men - -	65 ditto

The whole work is carried on by means of European supervision, a European being always treated with respect. The climate, though hot, is healthy.

The Kemaman River affords means of communication with the coast, a distance of about 45 miles, the freight up and down averaging £1 per ton, and the mines have a small railway to the river, a distance of 4 miles, operated by a locomotive.

Another concession called Sunghie Ayam is worked by Chinese about 12 miles to the north of Bundi. Here a small lode carrying some rich tin in places is being mined by the Chinese without European supervision. The lode is very flat, following the granite at an angle of 33°. The method employed is to stope the rich ore by means of parallel drives, and the timbering would not disgrace a European miner. The ore is first burnt, and then crushed by hand stamps and roughly dressed by sieving and streaming the ore in a sluice box. There are some big alluvial flats near the river which are worth prospecting, as the water proved too heavy for the Chinese methods of working. Tin is found up the coast by the Malays and Chinese for over 100 miles north, and the writer is of the opinion that this part of the Malay Peninsula is destined to become the Cornwall of the East for lode mining.

Extract from report on the Tin Deposits of Taiping, Malay Peninsula—by Geologist to the Federated Malay States, 1904.

Of the actual occurrence of mineral lodes there is little to be said. Two have been worked for tin, one at Selama, the other at Blanda Mabok. Of the direction and extent of the former I have as yet been unable to get any information; but close to an open shaft in the jungle I was shown some of the débris that had been brought up, and found it to be silicified sandstone. From a specimen in the Taiping Museum it is evident that the ore was very coarse. The report quoted above gives no direction for the Blanda Mabok lode. This contains cassiterite in coarse crystals, silver-lead as galena, which was also worked, and 2 dwts. of gold to the ton. I may mention that I cut a section from a specimen taken from a dump of the wall of the lode, and found that it was composed of fine-grained quartzite, containing brown tourmaline in the ground mass, and parallel bands composed of brown tourmaline, iron pyrites, calcite, and quartz. One other specimen that I collected showed that there had been brecciation of the wall of the lode.

The bulk of the alluvial tin was certainly derived from the granite. For present purposes, however, it is necessary to go somewhat more into details on this question. It has been suggested that possibly some of the cassiterite crystallised out together with the minerals forming the pegmatic and tourmaline granite, a suggestion perhaps warranted by the peculiar alluvial tin deposit at Ayer Kuning; but I have as yet seen no indication of this having taken place to such an extent in the Taiping range as to warrant a search for payable deposits of such a nature. The chief source of tin has been the small fissures which were formed either after the pegmatite had consolidated, or which had not been reached by the residual when it was first irrupted. These fissures, which from the specimens in the Taiping Museum appear to have been chiefly in granite, were formed as a result of the cooling of the exterior of the granitic mass; and there is reason to suppose from the mode of occurrence of such fissures in the tin districts of Saxony and Cornwall that they do not extend for any great distance into the granite. In the Taiping range it would probably be found, if the vegetation permitted, that over certain areas, perhaps restricted now on account of the denudation that has taken place, there is a network of these fissures, filled with quartz and bearing coarse crystals of cassiterite. Such a network constitutes a *stockwerk*, the typical occurrences of which are in Saxony.

The specimens from Waterfall Hill show that greisen has been produced on the sides of the fissures, and there is an abundance of micaceous pebbles of a similar nature in the mines; therefore I have no doubt that the chief source of the alluvial tin was a *stockwerk* similar to those in Saxony. How much has been denuded, and how much has been left, cannot be told without a minute examination of an enormous area of the hill-sides; but it would be indeed strange if it had been entirely washed down into the plains. Judging from Saxony, this *stockwerk* should prove worth working *in situ*; but the work would have to be carried on on a large scale and with a big modern plant; for it may be taken for

granted that if there is any tin in the rock intervening between the veins it is very finely disseminated, and that in the veins themselves is bunchy. Some of the veins may contain enough tin to be worked singly at a small profit; but it must be borne in mind that at a moderate depth such a vein must be expected to disappear entirely.

This leads to the question, are there any deep lodes in the granite or in the shale and sandstone series? Now the existence of tin lodes of any magnitude in a stanniferous area depends on the presence of faults which allowed of the passing of the tin-bearing media, which means that they must be faults of some size. Such faults in the granite must have been formed when the granite was cooling, and before the ejection of the tin from below. In the granite I have seen no evidence of the existence of such lodes, but I do not wish to assert that there is no chance of their being found. In the shale and sandstone there are three, that at Selama, the Klian Besar lode at Kurau, and the Blanda Mabok.

The Blanda Mabok lode presents several points of interest. In the first place, the association of tin, galena, silver, and gold, is exceptional. The lead appears to represent the copper of the Cornish lodes. Again, all the specimens I have seen from this lode show the cassiterite to be very coarse in grain; and it is known from Mr. Leonard Wray's report that it occurs in bunches. Also there is evidence of brecciation of the walls of the lode, and of the action of boron on these walls in the presence of tourmaline. The presence of tourmaline in the walls of the lode shows that its formation was connected with the granite intrusion, and that it became a lode approximately at the same date as the formation of the *stockwerk*. The brecciation shows that it is a fault fissure filled by the tin-bearing media from the granite, which, of course, involves a connexion of the fault with the granite mass either in depth or laterally, and gives some reason for supposing that the lode may be continued into the granite. In fact, but for the curious association of minerals, this would pass as a Cornish tin lode, and such a lode would be expected to prove rich in depth. There is another point which may be mentioned. Among Cornish miners there is a saying that as you go down in depth on a lode the tin gets finer in grain. Again, in many Cornish lodes copper ore is, or rather was, abundant in the higher levels, but was found to give way to tin in depth. Assuming, then, that I am right in considering that the galena at Blanda Mabok occupies a position analogous to that of the copper in Cornwall, the lode should be richer in tin in depth. If, then, the direction and underlie of the lode were accurately ascertained and a shaft sunk to strike it at 50 fathoms, all the evidence leads me to believe that good tin ore would be forthcoming, which, if the prices of tin and labour were favourable, would be welcomed in Larut when the prospects of alluvial tin mining are waning.

Another question is, is there any prospect of finding a system of lodes roughly parallel to one another in the shale and sandstone series here like that in the killas of Cornwall?

Petrologically, the killas of Cornwall is very like the shale and sandstone series; but that is no reason why the latter should also contain a

system of tin lodes. The existence of such a system depends on the state of the rock into which the granite was intruded. Now, in Cornwall, there is evidence to show that before the granite was intruded the killas had been subjected to enormous disturbances, so that when the earth movements connected with the granite intrusion commenced, they operated on a country already crushed and therefore more susceptible to the formation of faults than a country which had not been disturbed since its deposition. On the other hand, the shale and sandstone series shows much less evidence of disturbance than the Cornish killas, and it is my opinion that before the Taiping granite was intruded no earth movements of any importance had disturbed the series since its deposition. The probability of finding a big system of lodes like that in Cornwall is then remote; and this makes it extremely important to lose no time in collecting every available scrap of evidence leading to the location of such lodes as do exist. Even if such evidence consisted of nothing more than the discovery of sulphides, it would be of value, for lodes containing sulphides apparently alone on the surface might reasonably be expected to contain tin in depth. A time will certainly come in Larut when the alluvial tin will be worked out; and then miners, unless they desert the district, will be faced with the alternative of working the *stockwerk* and lodes, or the tailings from the alluvial mines. It is not necessary to point out of what immense value data such as those indicated would be under the circumstances.

In the Malay Peninsula stanniferous cement deposits occur at Bukitt Ebu near Kernai, on the south side of the range, and Dreda and Goa Tumbus in Ialor on the north side. In appearance these cement deposits resemble a siliceous bog iron, and have been formed by the disintegration of granites containing the tin ore. Near the granites occur large bodies of pyrites; the iron from these pyrites has cemented the small grains of quartz with the tin stone into a compact mass. The method of mining employed by the Chinese is to break it out and to crush it by means of foot stamps. As one would expect from its nature, it is of very unequal value.

French Mining Company at Lahat.

This Company has opened up what may be termed a lode. The lode is 8 ft. wide with a NE-SW. strike, and dipped at a steep angle to the west. It was composed of an intimate mixture of red iron oxide and cassiterite with a little iron and copper pyrites, the gangue being calcite and limestone, while there were some very large and beautiful crystals of calcite on the hanging-wall. The walls were fairly well defined. The granite contact was a mile to the west of the mine. The ore carries about 20 per cent. of tin. In Kinta these deposits have not lived down; at Lahat 35 feet has been sunk with good results.

The average output of tin F.M.S. from lodes is about 1·4 per cent. of the total produced.

CHAPTER VII.

TIN DEPOSITS OF NEW SOUTH WALES.

*In the beginning of 1872 public interest in New South Wales was aroused by the accidental discovery of tinstone, by the Messrs. Fearby, at Elsmore, near Inverell. Mr. Cleghorn, of Uralla, had sent the Messrs. Fearby to prospect the creeks of this district for gem-stones, the best localities for which were pointed out to them by an old shepherd on Newstead Station, named Wells. Mixed with a number of sapphires and other gems, in the gravels of the creeks, was a heavy black mineral in water-worn grains, which the Messrs. Fearby, supposing to be tinstone, sent to Sydney to be assayed for tin. The result of the assay proved that this black mineral was oxide of tin, and, the discovery becoming known, Baron and Moxham, and other capitalists, took up the ground near the present Elsmore Mine. Then commenced the rush to the New England Tin-fields. The stream tin under the title of "black sand" had been long familiar to gold-miners in New England, at Oban, and elsewhere, where its weight, rendering it difficult of removal from the sluice-boxes, had caused it to be regarded as worse than a nuisance. As knowledge of its value spread, eager prospecting led to its presence being proved over wide areas—areas which have been constantly extended since this discovery of tin at Elsmore, in 1872, until the latest finding of tin at Gumble, near Molong, in 1885. . . . Vegetable Creek is only 34 miles distant, in a direct line north-north-east from Elsmore, so that at the time when prospecting for tin was being so vigorously prosecuted in its neighbourhood, it was impossible for such a rich stanniferous area to remain long unknown; and in March, 1872, Thomas Carlean first discovered stream tin here, near the source of Vegetable Creek.

Mode of occurrence.—Its mode of occurrence is somewhat analogous to that of gold, and in a very considerable number of instances detrital gold and cassiterite are found in the same alluvial deposits. The principal deposits of tinstone are :—

(1) Recent and Pleistocene Alluvials.
(2) Tertiary alluvial deposits (Deep leads).
(3) Lodes.
(4) Stockworks.
(5) Impregnations.

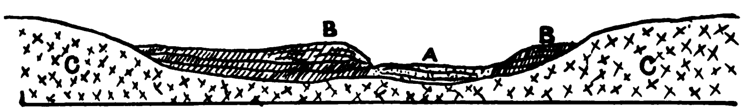
* "The Mineral Resources of New South Wales," by Ed. F. Pittman, Government Geologist, published by Mines Department, 1900.

The two first-named deposits are the sources of most of the tin hitherto obtained in the Colony.

Recent and Pleistocene alluvial deposits.—The principal stanniferous deposits occur in New England, in the Inverell and Emmaville Districts. As already stated, they were first worked at Elsmore, near Inverell, in 1872. In this locality the tinstone occurs as crystals disseminated through greisen, a crystalline granular rock consisting of quartz and mica. The tinstone is not, as a rule, in sufficient quantity in the griesen to render the latter a payable ore, but the gradual decomposition of the exposed portions of the rock has set free the crystals of tinstone, and these have been concentrated by the action of the rain on the hillsides into a surface alluvial deposit. Considerable quantities of tinstone were obtained from these surface deposits at Elsmore, and at the present time, especially after rain, crystals of the ore can be picked up on the surface. The tin in these deposits is associated with some wolfram, and also with carbonate of bismuth. The wolfram is derived from lodes which are known to intersect the greisen, and some of which are occasionally 18 inches or more in width. The tin, however, does not appear to occur in this locality in the same lodes as the wolfram.

Surface deposits very similar to those at Elsmore were extensively worked at Newstead, about 4 miles farther east, immediately after the discovery of those just alluded to ; and as the mining population, which had been attracted to these fields, spread out in their efforts to prospect the neighbouring country, Post-Tertiary tin-bearing alluvial deposits were found in the creeks and gullies at Stannifer, Tingha, Stanborough, and other places in the district. These deposits, being shallow, have for the most part been worked out, in fact most of them have been worked over several times by Chinese miners, who possess more patience than Europeans, and are satisfied with smaller profits.

The alluvial flats along the creeks traversing granite country in this district are all tin-bearing, but as these are of considerable depth, up to 20 feet or more, the stanniferous deposits require stripping, and are therefore not so easily worked. The bed of Cope's Creek was rich in tin ore from its source to its junction with the Gwydir River, and along its banks the Pleistocene alluvials were also a source of wealth to the tin-miners.



A. Recent alluvial 8 feet thick, with 2 feet of washdirt.

B. Pleistocene drift 16 feet thick, with from 1 to 5 feet of washdirt. *C.* Granite.

FIG. 18.—SECTION OF STANNIFEROUS ALLUVIALS AT COPE'S CREEK.

(After C. S. Wilkinson.)

A company has recently been formed for the purpose of working the stanniferous gravels in the bed and banks of Cope's Creek by means of a centrifugal pump dredge. The area acquired by the company extends down the creek for a distance of about 3 miles below the township of Tingha; very large quantities of tin were extracted from it by box sluicing in the early days of the field, and a certain number of Chinese have obtained a living by re-working portions of it for many years past. The operations of the company will be watched with interest, as this will be the first attempt to recover tin ore by this method of mining.

Middle Creek, which is four or five miles to the north of Cope's Creek, and flows into the McIntyre River, was also extensively worked for alluvial deposits of tinstone.

Sandy Creek, to the south of Cope's Creek, flows into the Gwydir River. Some tin ore is said to have been obtained from this creek near its mouth, but all attempts to prospect its bed for a considerable distance below its source were ineffectual owing to the presence of strong bodies of water in the sands. It is probable that dredging would be an effective method of overcoming this difficulty, and as this creek drains similar country to that traversed by Middle Creek and Cope's Creek, there appear to be fair grounds for believing that profitable returns would be obtained.

At Emmaville, where tin-mining was commenced very soon after the opening of the mines in the Inverell District, the most productive Post-Tertiary deposit was that known as the Vegetable Creek *lead*.*

Shallow alluvial deposits of Post-Tertiary age have been worked for tin in no less than twenty-seven localities in the Emmaville District, with more or less successful results. In the parish of Muir, masses or nuggets of black tin-ore were found close to the surface; the largest of these weighed thirty-two pounds.

Tertiary alluvial deposits (*Deep Leads*).—The tin-bearing greisen, the disintegration of which produced the rich surface deposits of tinstone, already alluded to, at Elsmore and Newstead, was also undergoing decomposition during early Tertiary times, and as a consequence of this large quantities of stream-tin were deposited in the valleys which received the drainage of this country during the Eocene period. The stanniferous deposits were covered with a considerable thickness of alluvium, consisting of gravel, sand, and clay, and containing leaves, nuts, branches of trees, and large logs, all of which are now preserved in a fossilised state. Eventually the valleys were invaded by streams of molten lava, so that they have since been protected from denudation by a considerable thickness of basalt.

The country intersected by these deep *leads* consists of hard bluish-grey claystones of Carboniferous age, and areas of intrusive granite and greisen. There are also numerous intrusive dykes of eurite, diorite,

* Much of the following information in regard to the Emmaville tin deposits has been obtained from Professor David's memoir on the "Geology of the Vegetable Creek Tin-Mining Field."

and basalt. Frequently on the higher ground are found deposits of Tertiary volcanic ash, which now consist essentially of the mineral bauxite.

The Elsmore Valley Lead, about ten miles south-east of Inverell, was, in the first instance, prospected by a bore. At a depth of 187 feet a bed of washdirt, 10 feet 6 inches in thickness, and estimated to yield 15 lb. of stream-tin per load, was intersected. At a depth of 201 feet 6 inches another bed of washdirt, 18 inches thick, and containing at the rate of 100 lb. of stream-tin per load, was met with, and 2 feet below this was a third deposit of washdirt 1 foot thick. This *lead* is now being worked by the Elsmore Valley Tin-mining Company, whose main shaft is 225 feet deep. The deposits of stanniferous washdirt are found to vary considerably in thickness, and occasionally the two lower beds intersected in the bore unite, while in other places they are separated by several feet thick of sand and clay. The yield of tin is also variable, but it is stated that the average contents are about 100 lb. of tin per load, and the mean thickness of washdirt is about 2 feet 6 inches. The tinstone is said to be of good quality, assaying from 76 to 77 per cent. of metallic tin when cleaned, and contains only a trace of wolfram.

The only mine opened on this *lead* is that of the Elsmore Valley Tin-mining Company, and comparatively little work has been done there, so that very little is known as to the extent of the deposit, and in view of the recent advance in the price of tin there is plenty of room for further development.

The Newstead Lead.—This *lead* was traced from surface deposits of tin-ore on the slope of a greisen range, and was found to deepen gradually as it was worked northwards, until, at the spot where it passes under Newstead Creek, Cody's shaft had a depth of 70 feet, and some hundreds of tons of tin-ore were extracted from this claim. The Newstead Company put down two shafts north of Cody's claim, and very rich deposits were worked from the first, which had a depth of 130 feet. The *lead* is said to have an average width of 140 feet. There is every reason to believe, especially in view of the enhanced value of tin, that there are payable deposits of ore here, which only require capital for their development. There is a number of other Tertiary tin-bearing *leads* in the Inverell District, such as *The Donegal Lead*, *Dick Jones' Lead*, *Brickwood's Lead*, *M'Millan's Lead*, *Standard Lead*, *Jealousy Lead*, *Walmsley's Lead*, *The United Lead*, *&c.*

Near the junction of Cope's Creek with the Gwydir River are several isolated basalt capped hills marking the course of an old Tertiary river-bed which once flowed approximately parallel with the Gwydir. Under the basalt is a considerable deposit, 14 feet thick in places, of well water-worn quartz pebbles, with large boulders of decomposed granite. This alluvial drift rests on a granite bottom, and is at the present time being worked for diamonds, which occur in considerable quantities, but of small size. The diamonds are accompanied by topaz, sapphire, zircon, tourmaline, ilmenite, magnetite, spinel, pleonaste, &c., and the washdirt contains, in addition, up to as much as 15 lb. of stream

tin per load. Although the tin is not, therefore, in sufficient quantity to render its extraction, *per se*, profitable, it forms a by-product, the value of which goes a considerable way towards covering the cost of extracting the diamonds. The gems just enumerated are also found associated with the stream tin in Cope's Creek, and many of the other watercourses in which stanniferous deposits have been worked in the Inverell District. With the exception of the diamond, however, none of them is of any commercial value.

In the Emmaville or Vegetable Creek District the Tertiary alluvial deposits have been divided into two classes, viz. (*a*) those which are capped by lava; and (*b*) bare deposits, or those from which the cap of lava has been removed by denudation. Examples of the latter class occur at Scrubby Gully, Surface Hill, Ruby Hill, and Y water-holes. The deposit at the Y water-holes is by far the most important of this class. It has an area of about 1,100 acres, and its depth averages about 20 feet. The alluvial deposits of clay and sand show characteristic current bedding. The ore is richest at the base of the beds, while the surface deposits contain more stream tin than the intermediate beds, owing to their having received the ore from the sluicing of a considerable thickness of sands which at one time overlay them, but which have since been removed by denudation. There is no evidence of the concentration of ore in old channels in this deposit, and it is therefore probably of lacustrine origin.

The following are the principal basalt-capped Tertiary *leads* which have been worked for tin in the Emmaville District:—

1. *The Vegetable Creek Lead*, including the basaltic country to "Kangaroo Flat," "Hall's Sugarloaf," "Paddy's Sugarloaf," and "The Surprise."
2. *The Graveyard Lead.*
3. *The Springs Lead.*
4. *Rocky Creek Lead.*
5. *Ruby Hill Lead.*
6. *Wellington Vale Lead.*

Of these, the Vegetable Creek Lead has proved to be by far the most important, and there can be no doubt that in early Tertiary times it formed the main drainage channel of this country. In portions of its course there were two distinct flows of lava, an older and a newer, each covering a bed of stanniferous washdirt. Up to the year 1886 the produce of these latter was 6,000 tons of stream tin in a distance of 2 miles 30 chains. At one place an area of 5½ acres of gravel, having an average thickness of 3 feet, yielded 2,000 tons of tin-ore. The main direction of the lead was west, and its width varied from a few feet up to, in one instance, as much as 400 feet. The thickness of the deposit of washdirt was occasionally as much as 14 feet; but its average was about 3 feet. Blank spaces were occasionally found in the lead where the fall of the old river-bed was steepest, owing to the tin-ore having been washed down to where the bottom was more level.

The Vegetable Creek Lead had two main feeders or tributaries, viz., the old *Rose Valley Lead* and *Fox's Deep Lead.*

The *Graveyard Lead* is south of, and approximately parallel with, the *Vegetable Creek Lead*, and the two *leads* probably junction about six miles west of Emmaville. A considerable amount of basalt-covered country runs from this point in a northerly direction through Kangaroo Flat to Avoca and the Fishing Grounds, and, as stanniferous drift has been worked at these places at a sufficiently low level to allow for the average fall of the old river valley, it is probable that the main *lead* will ultimately be proved for a distance of at least 15 miles, though it is scarcely probable that the tin-bearing washdirt will be found to be continuous; on the contrary, it is much more likely that stretches of unproductive alluvial deposits will be encountered, where the old river has intersected country which is not tin-bearing.

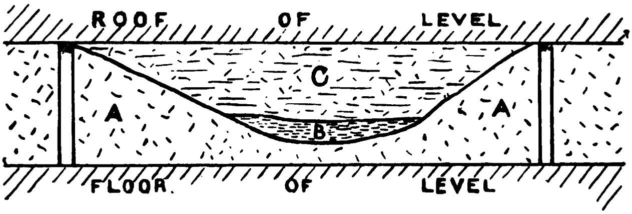
The greatest depth from the surface at which a *deep lead* in the Emmaville District has been worked is about 250 feet. In Wesley Brothers' mine, at the junction of *Fox's Deep Lead* and the *Vegetable Creek Lead*, the shaft, after passing through several distinct flows of basalt, penetrated a layer of gravel at 247½ feet from the surface. This gravel also rested on an eroded surface of basalt, so that there is a possibility of another alluvial gutter occurring at a still greater depth.

The Wellington Vale Lead.—The head of this old Tertiary alluvial deposit is situated at a locality known as The Nine Mile, to the north-west of Deepwater. Rich shallow deposits of stream-tin have been worked here along a flat trending from the south-eastern slope of Battery Mountain; but after being followed to the east and north-east for about a mile, they were found to dip below the basalt, a narrow strip of which extends southwards for some miles, forming a covering to the *Wellington Vale Lead.* No shaft has ever been bottomed in this alluvial deposit under the basalt, although a number of attempts have been made to prospect it. The cause of failure in each instance has been the quantity of water met.

The geology of Emmaville is, in most respects, very similar to that of the country round Inverell. The oldest sedimentary rocks are the bluish-grey claystones of the Carboniferous period, and these have been intruded by tin-bearing granites, and by quartz, felsites, and diorites. There was a great amount of volcanic activity during Tertiary times, as is attested by the sheets of lava, and deposits of volcanic ashes. These latter occupy an area of nearly 12 square miles, and they vary in thickness from a few feet up to 40 feet. The beds consist at the surface of a red dusty soil, and pass downwards into red, yellow, or grey tuffs, and compact pisolitic rock containing a variable percentage of alumina and peroxide of iron; these in their turn graduate into rotten spongy basalt. These ash deposits consist essentially of the mineral bauxite, and will doubtless be of considerable value in the future for the manufacture of the metal aluminium.

At Bailey's Mine, Rose Valley, there is an extremely interesting occurrence of a stanniferous alluvial *lead* overlaid by a felspar-porphyry lava. This occurrence was first recorded by Mr. S. H. Cox,

and is the only known instance in Australia of a *lead* covered by an acidic lava. (Journ. R. Soc. N.S.W., Vol. XX., 1886, p. 105.)



A. Felspar porphyry. *B*. Tin wash. *C*. Felspar porphyry.

FIG. 19.—SECTION ALONG PROSPECTING DRIVE IN BAILEY'S MINE.

(After S. H. Cox.)

Bailey's Mine is situated on the junction of intrusive felspar porphyry with the Carboniferous claystones, and the floor of the *lead* is formed sometimes of the one rock and sometimes of the other, in different parts of the mine. It is probable that the acidic lava covering the washdirt was nearly contemporaneous with the basalts which are found overlying the other deep *leads* in the district, and represented the earlier products of the volcanic eruptions.

Associated Minerals.—The following minerals are found associated with the stream tin in the Emmaville deep *leads*, viz. :—Magnetite, ilmenite or titaniferous iron, tourmaline, spinel (pleonaste), quartz, topaz, zircon, sapphire, and beryl (emerald).

Tin-bearing Lodes.—The stanniferous lodes in the Inverell and Emmaville Districts comprise (*a*) Fissure Veins, (*b*) Joint Veins, or those following joints in the granite or felspar porphyry, and (*c*) Pipe Veins. The veins are found most frequently in the granite, and they occur almost exclusively within a distance of about a mile and a half of the junction between the granite and the claystones. Professor David states that in the Emmaville District—

76	veins	are enclosed	in	granite.
8	,,	,,	,,	quartz porphyry.
3	,,	,,	,,	porphyroid.
3	,,	,,	,,	claystone.

He also noted that out of seventy-seven veins in this district in which tinstone occurs, nineteen consist of quartz and tinstone only, and eight of felspar and tinstone only ; also that sixty-nine veins contained quartz, twenty-nine contained chlorite, and twenty contained felspar. The following minerals also occur in different veins in the district, viz., mica, mispickel, iron pyrites, fluorspar, tourmaline, wolfram, zincblende, galena, copper pyrites, bismuth, molybdenite, vesuviante, stilbite, hematite, pyrrhotine, manganese, scheelite, and beryl.

Strike of Lodes.—The average strike of fifty-four right running veins was found to be N. 39° 15′ E., the range of strike being from N. 24° E. to E 20° N.

Dip.—The average dip of thirty-seven veins observed was 77°.
33 veins dip north-westerly.
10 „ „ south-westerly.
3 „ are vertical.

Those veins, or portions of veins, which most nearly approach the vertical have, so far, proved the richest.

Length.—The greatest length for which a vein has been proved to be tin-bearing is about one mile.

Width.—The average width of sixty-nine veins is 1 foot 6¾ inches. The six largest veins hitherto worked have the following thicknesses, viz.:—

No. 1 Ottery vein - - -	3 feet.
No. 2 Ottery vein - - -	4 „
Butler's vein - - - -	3 feet 2 inches.
No. 1 Dutchman's vein - - -	4 „
No. 2 Dutchman's vein - - -	3 „
Curnow's vein - - - -	3 „

The majority of the other veins are narrow.

The ore in most of the stanniferous veins occurs in *chutes*, which are inclined more or less steeply from the horizontal, and obliquely along the plane of the lode. The average length of the six largest

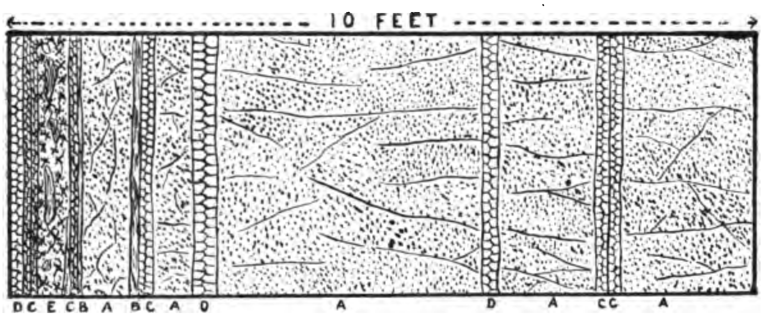


FIG. 20.—SECTION SHOWING CHARACTER OF BUTLER'S VEIN, EMMAVILLE DISTRICT.
(After T. W. E. David.)

chutes observed was 100 feet; average width 1½ feet; average depth 6 feet; average dip 26°; average horizontal distance between *chutes*, about 80 yards; vertical distance between *chutes*, 50–90 feet. Eleven *chutes* were observed to dip north-easterly; two *chutes* were observed to dip south-westerly.*

* T. W. E. David—"The Geology of the Vegetable Creek Tin-mining Field."

Stanniferous pipe veins are a peculiar feature of both the Emmaville and Inverell Districts. They occur in granite as a rule, and are cylindrical or oval in form. They sometimes dip at a considerable angle; at other times their course downwards is vertical. They do not often extend to any considerable depth, thinning out at about 30 or 40 feet. They are occasionally as much as 4 or 5 feet in diameter, and within these limits the tinstone occurs disseminated through a gangue of felspar, quartz, and chlorite. Several of these pipes, or "shoots" as they are termed by the miners, are at the present time being worked in the vicinity of the Nine Mile; they are all very similar in their mode of occurrence, the chief difference being in the diameter of the deposit. The following particulars of one of them may be quoted: Messrs. Crocket and Knight's tin-bearing pipe vein is situated in granite country on the bank of the Bark Hut Creek, about 12 miles north-west of Deepwater. Where originally found the pipe vein was nearly horizontal and had a southerly trend; it was about 3 feet in diameter, and in a distance of a few feet it yielded 8 tons of tinstone, when it thinned out to an inch or two in diameter, and was abandoned. Subsequently, when tin had risen to a better price, the present owners started to reopen the deposit, and soon found that it increased in diameter and assumed a vertical course. It was followed down for about 15 feet, having a diameter of about 2 feet 6 inches, and then gradually became horizontal again. The excavation now measures about 40 feet from the surface, and the deposit has forked or divided into two pipe veins, each of which is about 9 inches in diameter. The proprietors have taken out about 4 tons of tinstone since reopening the deposit, so that the total yield has been 12 tons up to the present. The gangue consists of green felspar, and crystals of cassiterite thickly disseminated through this. The average yield of the ore is 10 hundredweight of tinstone per ton, and the tinstone contains from 75 to 76 per cent. of metallic tin.

Stockworks.—Minute veins of tinstone occur in quartz porphyry or felstone in many places in the Emmaville District, forming what are known as stockworks. The minute veins appear in many cases to follow joints, which cross one another in several directions in this intrusive rock. They have not, so far, proved payable to any considerable extent.

Impregnations.—Allusion has already been made to impregnations of tinstone in greisen at Elsmore and Newstead, in the Inverell District. At Pheasant's Creek, to the east of Glen Innes, some extremely rich deposits of tin-greisen have been found, but these were limited in extent. Impregnations of tin-ore are also found alongside joints in the granite in the Emmaville District, and the pipe veins already described might also be considered to belong to this class of deposit.

The Ottery Tin-lodes.—These lodes are situated about two miles to the north of the village of Tent Hill. There are at least five distinct lodes, and they occur intersecting dykes of hornblendic granite and eurite, within a distance of a few chains from the junction line of these intrusive dykes with the Carboniferous claystones. The lodes strike north-east and north, and their dip is towards the north-west and west,

at angles varying from 30° to 80°. One of these is the only stanniferous lode at present being worked in the vicinity of Emmaville, though others are being worked by small parties of miners in the neighbourhood of Torrington and The Nine Mile. As mining operations have been carried on in connection with the Ottery lode for more than sixteen years, a brief description of the deposit may not be out of place.

The outcrops of all the Ottery lodes consist of ferruginous gossany quartz containing tinstone, and may be traced on the surface for a considerable distance in a south-westerly direction towards the head of the old (Pleistocene) *Vegetable Creek Lead*, and there can be very little doubt, therefore, that the extremely rich deposits of stream tin which were recovered from those shallow alluvials were derived from the denudation of portions of the Ottery lodes, and from stockworks occurring along their line of strike.

The oxidised or gossanous portion of the lodes extends to a depth of from forty-five to seventy-five feet, and in the worked-out portions of the mine the walls of the shafts and drives within this zone are quite green with an efflorescence consisting of sulphate and arseniate of iron. Below the zone of oxidation, the ore passes into compact mispickel and quartz, containing tinstone. In some places the lodes are characteristically banded ; in others the mispickel is quite massive. The main lode has been worked at the surface for a length of about 1,000 feet, and at the 230-feet level it has been worked for a length of about 750 feet. In two places the upper portions of the lode have been removed by open cuts, and there are also three shafts, the two deepest of which are 300 and 350 feet respectively, measured on the underlie. On the top of the hill, near the most southerly shaft, a lump of tinstone was found weighing 2 cwt. 1 qr. 24 lb., and assaying at the rate of 72 per cent. of metallic tin. At a depth of 50 feet from the surface a shoot of ore was met with which dipped northerly at an angle of about 20°. This shoot was 90 yards long, 5 yards high, and varied from 4 inches to 1 foot in width ; it consisted of nearly solid tinstone. In the upper workings of the mine the more highly inclined portions of the lode were found to be richer in tin than those portions in which the dip was slight or moderate. At a depth of 70 feet, in the middle (or deepest) shaft, the lode was split by a "horse" of granite, which continues to the 300-feet level. The two portions into which the lode is thus divided are known respectively as the foot-wall lode and the hanging-wall lode. They vary in width from 6 inches to 4 or 5 feet, and are usually banded in character. The "horse" is tin-bearing, but is usually of low grade. The maximum width of the mineralised formation, including the two lodes and the "horse," is 30 feet. In places the horse has all the character of a stockwork, consisting of a matrix of hornstone and quartz, intersected by minute veins of quartz showing tinstone and arsenical pyrites. Occasionally the full width of the formation has been extracted for a width of more than 25 feet, and some remarkable timbering is to be seen, consisting of stull pieces, having a length of as much as 27 feet 6 inches. The presence of considerable quantities of arsenical salts in the mine-water appears to have

a wonderful effect in preserving the timbers, and dry rot is apparently unknown here. In the upper levels the lode was characterised by clean and well-marked walls, showing slickensides, but in the lower portions of the mine there are seldom any signs of defined walls, and the country outside the hanging wall and foot wall lodes is as much mineralised as the "horse" which separates them. Occasionally specks of copper pyrites and small crystals of galena and zincblende are seen in the lodes, but these minerals never occur in any quantity.

The ore raised from the lower levels of the mine has for some considerable time past yielded less than 3 per cent. of tinstone, so that it is essentially a low grade as well as a refractory ore.

The lode has, for the most part, been worked by underhand stoping the workings keeping pace with the excavation of the shafts. This is, for many reasons, an unsatisfactory method of exploiting, but its adoption is probably due to the continued low grade of the ore, and the consequent disinclination of the owners to incur the expense of sinking the shafts to a sufficient depth below the working faces to allow of the subsequent removal of the ore by overhand or back stoping.

Other Lodes at the Ottery Mine.—There are several other parallel lodes at the Ottery Mine which have, as yet, been scarcely prospected; one of these is situated about fifty feet to the east of the lode now being worked, while another, which, judging by its strong outcrop, would appear to be much the largest deposit in the district, is situated about 200 feet still further to the east. There is every reason to believe, therefore, that very extensive deposits of lode tin exist in the neighbourhood, though the mining operations hitherto carried out show that much of the ore is of lode grade. However, if ore containing less than 3 per cent. of tin could be made to yield a margin of profit in spite of the low price of the metal which has ruled for some years past, the future should surely be hopeful in view of the largely increased price now obtainable. In 1905 the Ottery Mine, Tent Hill, raised and treated 2,500 tons of ore averaging 36 lbs, of Tin ore to the ton. This returned 41 tons of ore valued at £3,250.*

The Jingellic Tin Lodes.—On the southern border of New South Wales tin occurs in lodes at Jingellic, about sixty miles to the east of Albury. Here again the mineral is found under the geological conditions which mark its occurrence in the northern fields: that is to say, the deposits occur in granite, close to its junction with slate rocks.

The lodes at Jingellic are situated principally in a high granite range extending along the northern bank of the Murray River, at the head of Swamp Creek. A flat about a mile in length extends from the bank of the Murray up to the foot of the range, and here the Swamp Creek forks, the western branch being known as Little Swamp Creek. A company, known as the Jingellic Tin-mining Company, formerly held about four hundred acres here, a considerable portion of it being freehold land, and they also held the right to mine for stream-tin on the flat; much of their capital was, however, expended in

* Official Mines Report, 1905.

unproductive work, and they suspended operations about eighteen years ago, although very little actual prospecting of the lodes had been done.

In the ranges above the flat no less than eight well-defined quartz lodes occur, all carrying tin in greater or less quantity. No. 1 lode on the range is situated at an elevation of about 900 feet above the river. It strikes east and west, and is almost vertical, having a slight dip to the north. A tunnel was put in along the course of this lode for a distance of 160 feet, and a winze was sunk for a depth of 30 feet. The lode was found to vary in width from 10 inches to 2 feet, and the quartz, in places, contains a large amount of tourmaline, with some wolfram and a fair sprinkling of tinstone.

The most northerly lode is know as No. 6, and is situated about a thousand feet north of No. 1, at an elevation of between 1,000 and 1,100 feet above the Murray. It also has an east and west strike, and, so far as it has been tested, varies from 4 feet 6 inches to 6 feet in width. Its outcrop has been traced for a distance of about a mile. It appears to contain fine tin in streaks through the quartz, with only traces of wolfram and tourmaline, while the casing carries coarse tin. A shaft was sunk 70 feet on the lode (which measured 4 feet 6 inches in width at that depth), and a tunnel was driven through the granite to cut the lode at right angles. It was said that 10 tons of stone crushed from this lode yielded 16 cwts. of tinstone. About 20 feet from this lode, and running parallel with it, is a smaller one, varying from 4 inches to 2 feet in width, and similar in character, carrying streaky tin in the body of the stone, and coarse tin in the casing.

Between Nos. 1 and 6 four well-defined lodes occur, the outcrops having been discovered to the westward of the two just mentioned, and at a higher elevation on the range. The nearest to No. 6 is a 2 feet lode, bearing north-west and south-east, and therefore probably junctioning with No. 6. No. 5 also probably junctions with No. 6 on the south side. It bears north-east and south-west, and was opened at an altitude of between 1,200 and 1,300 feet above the river. The small excavation shows it to be 5 feet in width, inclusive of a "horse" of granite 1 foot wide. The south side of this lode carries fair tin.

No. 4 lode bears E. 10° N., and is 4 feet wide on the surface, and 6 feet 6 inches wide at a depth of 10 feet. It contains much arsenical pyrites, some wolfram and tourmaline, and a fair percentage of tinstone. Its outcrop has been traced for a distance of eight chains.

The next lode to the southwards, No. 3, is also a wide one, being 4 feet at its outcrop. It contains streaky tin, and appears to resemble No. 6 in character.

Near the foot of the mountain, on Little Swamp Creek, is a lode known as No. 7. It averages from 2 feet 6 inches to 4 feet in width, and bears E. 38° S. A tunnel, which was driven from the foot of the hill, intersects a shaft in the lode at a depth of 76 feet. A drive was carried out to the east from this shaft, but the tin *chute* was found to run out.

Another east and west lode occurs about a chain north of the last mentioned; it is about 2 feet 6 inches in width at its outcrop, and was

formerly thought to be identical with No. 7. It contains coarse tin, but appears to be patchy.

No. 8 lode, situated several chains still further south, varies from 10 to 18 inches in width, and strikes east and west. A shaft was sunk on this for a depth of 70 feet.

The Dora Dora Deposits.—Tin also occurs in granite country at Dora Dora, in the parish of Vautier, county of Golbourn, about 40 miles east of Albury. A narrow swamp, through which Basin Creek flows, extends back from the Murray River for several miles; a stanniferous drift has been proved to occur in the alluvials along the course of the creek.

The Pulletop Deposits.—Tinstone also occurs, both in lodes and alluvial deposits, about twenty miles from Wagga Wagga, in the parishes of Pulletop, Burrandana, and Westby, county of Mitchell. Here again the lodes occur within a short distance of the junction of granite with slate. The gangue of the lodes is quartz, and the tinstone, which is accompanied by a considerable portion of wolfram, is only present in small quantity. The largest lode has a width of about 3 feet. Several attempts have been made to work the alluvial deposits derived from the denudation of these lodes, but they have not so far proved remunerative, owing to the fact that tinstone and wolfram are present in about equal proportions, and the product was unsaleable in Australia. It is probable, however, that with the introduction of magnetic separators payable results could be obtained from the working of the drifts.

The Burra Burra Deposits.—At Burra Burra, about sixty-five miles to the north-west of Parkes, an alluvial *lead* containing tinstone was discovered in the year 1893, and was worked for a short time, but the deposit was not found to be very rich or extensive, nor were the lodes from which the mineral was derived ever discovered, probably owing to the flat nature of the country. The depth of sinking in the alluvium was as much as 20 feet.

The Euriowie Tin Lodes.—In the far western portion of the Colony, at Euriowie and Poolamacca, about fifty miles to the north of Broken Hill, tin-ore occurs under conditions which differ materially from those of any of the deposits hitherto described. The Poolamacca and Euriowie field was reported on by the late Mr. C. S. Wilkinson in 1887, and by Mr. J. B. Jaquet in 1894. The ore from this district bears a most marked resemblance to that from the Harney Peak Mines of Dakota, U.S.A., so much so that specimens from the two places cannot be distinguished from one another.

At Euriowie the ore occurs in coarsely crystalline granite or greisen dykes, which intrude metamorphic rocks, such as gneiss and micaceous schist. The granite dykes are variable in their dimensions, being usually from 1 to 20 feet, and occasionally 100 feet in width, and terminating abruptly with rounded ends. Mr. Jaquet describes a curious symmetrical arrangement of the dykes which is sometimes seen at Euriowie. Ten or fifteen short dykes may be arranged in the same general direction, and nearly, but not quite, continuous, the posterior end of each being slightly to one side of, and overlapping, the anterior end of its neighbour; so that the series, when shown in plan, resembles

PLAN OF THE TIN-BEARING GRANITIC DYKES OCCURRING ON THE MOUNT EURIOWIE TIN MINING CO.'S PROPERTY.

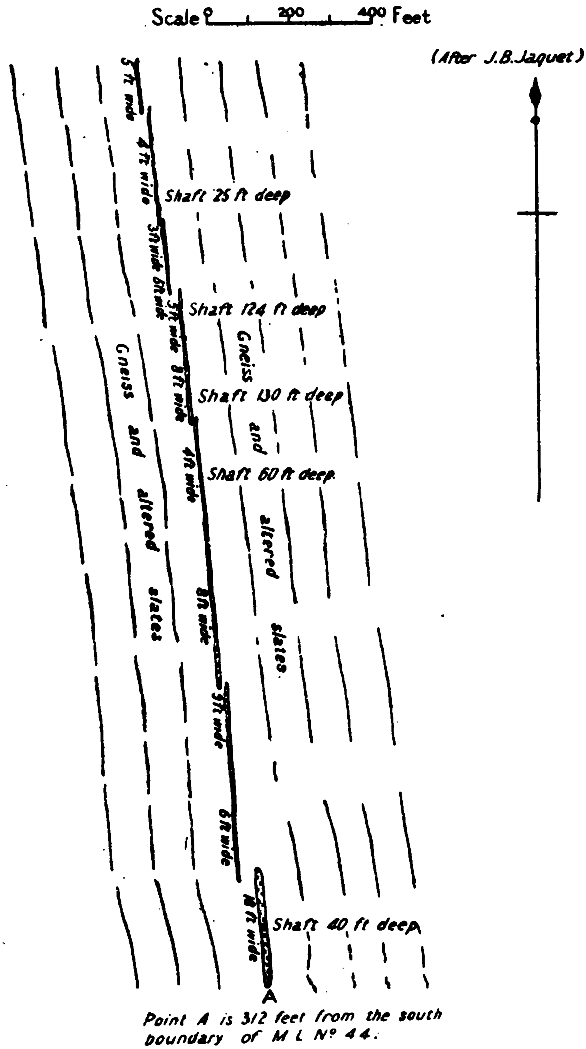


FIG. 21.

a lode which has been intersected and heaved by a number of parallel cross courses. There are, however, no cross courses.

The dykes are composed of coarse crystals of quartz, felspar, and mica, one or two of these minerals predominating at times ; thus the rock may be mainly composed of large flakes of mica, or of coarse crystals of quarts and felspar, or mica and quartz. The crystals of tinstone, which vary in size up to 2 or 3 inches in diameter, are not evenly disseminated throughout the gangue, but occur in irregularly distributed bunches.

The total product from the mines of New South Wales during 1905 was 804 long tons of metallic tin, valued at £188,377.

Tingha and Inverell Division.—There has been a considerable increase in the tin output from this district, fully 1,800 persons are engaged.

The locality known as Red Hill has received a good deal of attention, and a rich deposit of ore has been found at a depth of 100 feet.

At Pond's Creek great advancement is also noticeable.

Rich deposits have been opened up at Bora Creek, Barry.

Very little lode mining has been done, a quantity of stannite was raised by the Conrad Mines at Howell during the year and stacked for future treatment.

The dredges in this district have augmented the yield. A total amount of 468 tons of tin ore were won, valued at £44,739.

From all other sources in this district 689 tons of ore valued at £65,000 were recovered.

The total value of the tin won in 1905 in the Tingha and Inverell Division was £110,239 as against £59,769 for 1904.

Promising lodes have been opened on the Inverell Road, a mile and a half from Tingha, and at Red Hill and Stannifer, in the same locality. In the Emmaville Division 150 Chinese have been kept busy sluicing tailings which had been cast aside in previous years. Con siderable abandoned ground has been worked profitably, owing to the increased price obtained for tin and to improved methods.

In the Deepwater Division an excess of water caused some suspension of work. The Silent Grove Mine, the most important in this division, has yielded black tin averaging 8 hundredweights to the long ton of ore raised. The workings there have been advanced about 100 feet. The Nine Mile Deep Lead has not been worked. The expectations that work in the Broken Hill Division would be carried on actively were not realised, and most of the leases have been cancelled. Although no great extent of new ground is being taken up, yet the general indications are that the increased output will be maintained.*

Glen Innes Division.—The estimate for 1905 is £1,000 from ore raised, this has been caused by a partial failure of the Glen Elgin Dedging Company.

Rookabookra Division.—The miners working on the Mitchell River are recovering considerable quantities of tin ore with the gold, and an increased output is looked for from here.

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* Official Report of Secretary of Mines, N.S.W., 1905.

CHAPTER VIII.

TIN DEPOSITS OF QUEENSLAND.

TIN was first discovered in this colony at a place called Stanthorpe, not far from the New South Wales border, in 1872, and has since then proved an important item of production. Although not so widely distributed as silver or gold, tin has been found in many different parts of the Colony, notably on the Pascoe River, near Weymouth; at Bloomfield, near Cooktown on the Palmer River, the Barron Waters; Herberton, including Irvinebank and the Star River.

In 1896 tin was being mined for in six districts; but two-thirds of the output came from Herberton, and rather more than half from the Cook district. In this year the production of tin was seriously declining, but in 1903 and 1904 there was a big revival. The chief Tin Mining fields are as follows:—

The Herberton Tin Field lies among the hilly country to the west of the Herberton range, and is situated about 50 miles S.W. of the Port of Cairns. The Mareeba to Chillago line has constructed three branch lines to the tin-fields, which are very extensive, covering an area of about 12,000 square miles. The whole country is very mountainous, ranging from 2,000 to 4,000 feet above the sea.

The tin mines are scattered in groups on both sides of the mountains; the rugged nature of the country has added greatly to the high cost of haulage of ore and machinery, and the preliminary expense of opening the mines.

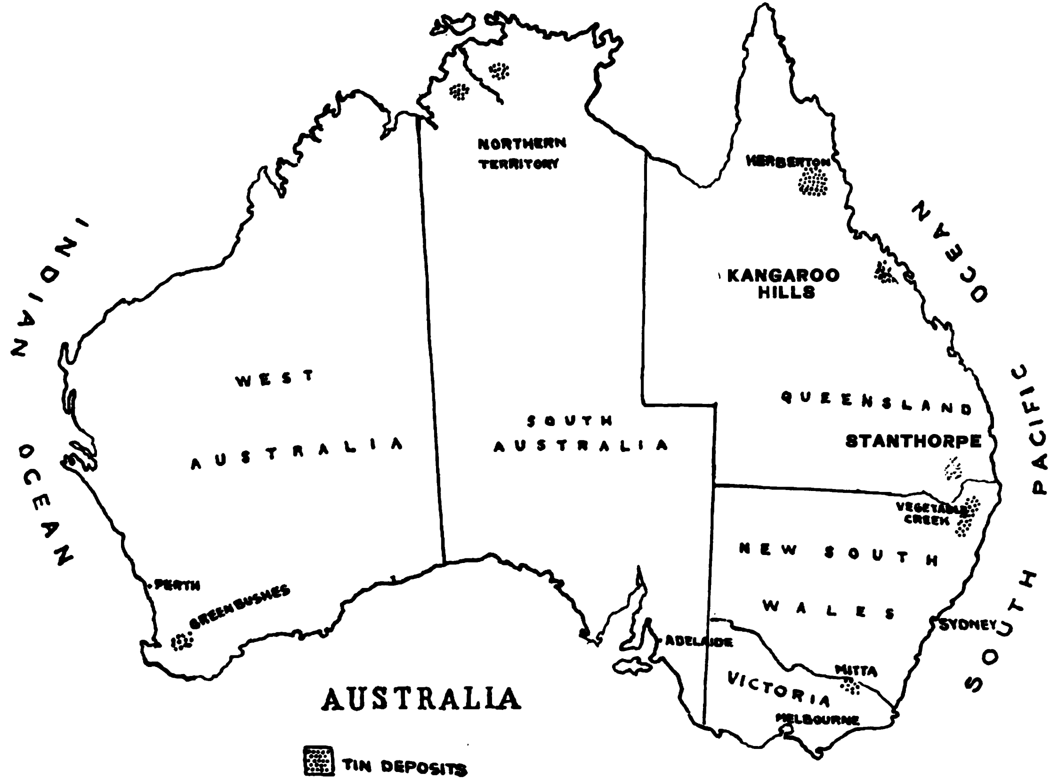
Kangaroo Hill Tin Field, situated about 80 miles from Townsville, to the N.W.

Stanthorpe Tin Field situated near the New South Wales border.

Tin has also been found near the Gilbert River in the west, near the old Palmer Gold Fields to the north, and several other places.

* HERBERTON TIN FIELD.—The oldest rock formation of this field is a series of alternating coarse and fine sedimentary beds. They have been folded and faulted by high pressures acting east and west, and are now generally found lying at high angles of inclination, their irregular and broken lines of strike running in northerly to north-westerly directions; these rocks have been altered by long ages of pressure and chemical change, till the coarser beds have

* W. E. Cameron, Assistant Gov. Geo., 1904, "The Herberton Tin Field," published by Department of Mines, No. 192.



MAP OF AUSTRALIA—SHOWING POSITION OF TIN DEPOSITS.

been metamorphosed into quartzites and greywackes, and the finer beds into slates and schists.

Subsequently denudation has removed them over the greater portion of the tin-bearing area, and has thus exposed the underlying granite rocks over the greater part of the district.

The sedimentary rocks cover a very large district south of Irvinebank, and occur in small areas near Watsonville, Stannary Hills, Koorboora, and California Creek. A great number of the more important lodes are associated with these rocks.

The plutonic rocks are Holocrystalline biotite or hornblende granite. There are large areas of eurite types, such as granite porphyry and quartz felsite. Lodes of tin occur in both. Dykes of elvan include both the plutonic and altered sedimentary rocks. The tin lodes are for the most part irregular in their manner of occurrence. The deposits of ore seldom lie along a well-defined course between the walls of country rock, but are as a rule distributed through it in an irregular manner, forming bodies of very varied size and shape. The lode material is only in exceptional cases separated by well-marked planes of division from the enclosing country. As a rule it merges into it, with a gradual change from lode material to barren rock. The lode material is in almost all cases evidently a product of the alteration of the country rock by the action of mineralising agents, which have changed its constitution by chemical action, and have at the same time deposited tin and other minerals within its interstices.

In the case of the granite rocks the alteration to lode material takes many forms, giving a variety of ores of widely differing appearances. The alteration varies, however, more in degree than in general character, and can, as a rule, be readily understood. The felspar and other silicates may be changed to serpentine or chlorite, or may be completely replaced by silica. In other cases the products of alteration are sericite and silica. In some cases very little alteration is noticeable to the eye, the tin occurring in grains through the apparently unaltered granite or porphyry. The results are ores varying through every degree of alteration, from the normal granite rock, splashed through with grains of tin, to purely silicious tin-bearing material.

In the sedimentary rocks the lode material varies from an almost unaltered quartzite, showing under the microscope crystals of tin in the interstices between its grains, to a massive green chlorite, which weathers on the surface to rusty-red kaolinic material. A normal sample of "chlorite ore" from the 500-feet level in the Vulcan Mine showed under the microscope a mass of grains of quartz and felted patches of chlorite, splashed through with crystalline grains of tin and magnetite. In the alteration of these greywacke and quartzite rocks also the silicate minerals have evidently been first attacked, and changed into chlorite by the mineralising solutions.

The fluoric minerals—topaz, fluorspar, and tourmaline—generally found associated with tin deposits, are of very usual occurrence, both in the lodes in the granite and those in the sedimentary rocks, while

the metallic minerals—wolfram, bismuthine, antimonite, galena, chalcoprite, and magnetite—are frequent accompaniments, often in sufficient quantities to be a source of considerable trouble in the treatment of the ore.

Character of the Mining.—The irregular manner of occurrence of the ore in these lodes has had a marked influence on the character of the mining in this district. In the case of mineral matter introduced along true fissures, extending with comparative regularity over considerable distances both horizontally and vertically, and carrying lode material between well-defined walls, or impregnating the country rock more or less evenly on either side, a certain amount of confidence can be displayed in prospecting and development work. If the lode becomes too narrow or too poor for profitable working, development work is pushed on either horizontally or in depth along the line of fissure, with a fair prospect of the lode again widening or improving in value along the same line. Where, however, no such irregularity of disposition of the ore exists, as in the case of most of the Herberton lodes, only the general run of the ore body can be followed as a guide for fresh prospecting work.

One of the most noticeable features of the ore bodies is the shortness of the shoots in horizontal extent. In the Launcelot Mine at Newelton, at the 150-feet level the lode has been stoped for 200 feet continuously on ore. The next longest working on a continuous body is at the 500-feet in the Vulcan Mine, where the stope has been carried along for about 150 feet on ore. At the 100-feet level in the Smith's Creek Mine the ore was taken out for about 78 feet in length. These, however, are three of the longest continuous shoots that have been worked on the field, the majority rarely reaching 50 feet in length. Nor do they often lead on to others in the same line connected genetically with them, and capable of being worked from the same shaft.

Their want of length is often compensated for, to some extent, by considerable thickness, and bodies of ore of nearly the same dimensions in either direction are of frequent occurrence.

The greatest hindrance to continuous and economic mining of these lodes is, however, the want of continuity of the shoots of ore as they are followed downwards. Repeated instances of unsuccessful attempts to pick up large and profitable shoots of ore by driving 50 feet or 100 feet below where they are being stoped have convinced the tin-miner in this district that his hopes of picking up a lost lode again in the position in which it might naturally be expected are more often disappointed than not. Frequently a long period of prospecting in different directions has to be gone through before fresh ore reserves can be developed, with often little or no indication except the general dip of the shoot above to serve as a guide.

The want of continuity of the deposits makes the economic location and proving of fresh ore reserves, in advance of those already developed and in course of extraction, a matter of the greatest importance. Where the lodes follow no true course, as such is understood with true fissure lodes, and where the break in the continuity is not

due to the faulting of the country subsequent to the formation of the ore body, it is useless to attempt to apply rules of procedure for finding lost lodes that have been framed to suit well-defined deposits with definite course and dip. The only course open seems to be that universally adopted by the experienced tin-miner—namely, to follow the tin as far as it will lead, in the hopes of its making into another body of ore, and when this can no longer be done, to use the individual judgment in prospecting in the most likely place in the most economic manner that can be employed. In this connection it seems likely that, in the case of large bodies of ore like those found in the Vulcan, Smith's Creek, and many other mines where the tin is disseminated with comparative evenness through an extensive mass of lode material, the diamond drill might be employed with advantage by saving much profitless driving and sinking, and allowing of the opening up of fresh ground in the most convenient manner. In any case the importance of keeping development work well ahead of present mill requirements cannot be too strongly insisted on with lodes of this character, if the undertaking is to prove profitable to the shareholders.

The small size of the great majority of the lodes, combined with their richness, has made them peculiarly adapted to return good profits to small parties of working miners. Their bunchiness and want of regular continuity when followed downward frequently gave rise to correspondingly irregular methods of working, often entailing two or three handlings of the ore before it could be brought to the surface. In this way the depths were soon reached at which it became impossible to handle anything but the richest ores at a profit, and the majority of the lodes were gradually abandoned before any great depths had been reached. Many of the larger ore bodies, especially amongst those occurring in the sedimentary rocks, were early found to be too poor for profitable mining with the low price ruling for tin before 1898. They were abandoned at shallow depths. Increased prices, however, inspired the hope that many of these could be made to yield profits if provided with batteries close at hand, and with the application of more up-to-date methods of mining.

*Last year's yield of tin amounted to 3,945 tons, of a value of £297,454, being an increase in quantity of 22 tons, and in value of £27,178.

More than two-thirds of the supply in 1905 has been derived from that portion of the *Walsh and Tinaroo Mineral Field*, which may be roughly described as extending from the town of Herberton, in a southerly direction, to the confluence of Return Creek with the Herbert River ; thence westerly about 15 miles ; thence north-west to Koorboora ; thence east-north-east to Stannary Hills ; and thence east-south-east to the point of commencement. Within this area of approximately 1,000 square miles tin is the principal paying product ; and, although it is probable that many valuable lodes have yet to be discovered, there are certain centres around which the productive mines are grouped, and

* Annual Report Secretary of Mines, Queensland, 1905.

which at present supply practically the whole of the lode tin of the district. Chief of these is Irvinebank, and there is the Vulcan, the deepest and the richest tin mine in Queensland. The straight shaft is now 1,100 feet deep, and at 1,050 feet a level is being driven for the lode. The lowest working level in tin ore is 900 feet, and from this point up to 675 feet there are large reserves almost untouched. Most of the year's output came from the 600-feet level, but stone is still being raised from the shallower parts of the mine, where it is quite possible that further exploration may disclose new bodies of ore. Next in rank to the Vulcan is probably the Governor Norman, a comparatively new discovery, which has, however, been opened sufficiently to furnish the assurance of the existence of a very large deposit of ore-bearing material carrying a little over 3 per cent. of tin. Although not so rich as the Vulcan, its great dimensions will, it is believed, when development work is more advanced, and when more crushing power is available, render it a formidable rival of that mine. There are in the neighbourhood of Irvinebank a number of other mines in various stages of development, all dependent for the treatment of their stone on the London mill; and, in order to relieve the pressure, it has been decided to reopen the mill at Coolgarra, which it is hoped will stimulate into activity that latterly somewhat neglected centre.

Next in productiveness to Irvinebank come Stannary Hills, where the Stannary Hills Mines and Tramway Company has, under the direction of a new manager, been entirely reorganised.

It must not be forgotten that the question of rainfall plays an important part in deciding upon the possibility or otherwise of working alluvial deposit to advantage, hence the very marked increase in the production of stream tin in the Herberton district during the last two years, due to a rainfall much in excess of that which has fallen for a number of years. For instance, the value of alluvial tin won during 1903 was £45,287, as against £7,835 for the previous year.

STANTHORPE.—Although immense quantities of tin have been taken from the creeks and flats of the Stanthorpe field, and the days of washing and cradling are over, there is still left much that may be recovered by modern appliances for the economical treatment of large quantities of material. With this object in view, two dredging companies have acquired considerable areas of tin-bearing country, and after numberless difficulties and delays are now in active operation.

STANTHORPE PROPRIETARY TIN DREDGING.—The annual report of the director of the Stanthorpe Proprietary Tin Dredging Company shows that during the past year the dredge recovered 93 tons 14 cwts. 5 lbs. of tin, for which the sum of £10,019 10s. was received. The expenditure totalled £6,069 4s. 6d., of which sum £2.303 15s. 11d. went in wages; renewals, repairs, &c., £1,522; sundries, freight, carriages, £539 10s. 1d.; firewood, £473.

THE KANGAROO HILLS MINERAL FIELD.

Geology.—The Kangaroo Hills Field covers an area occupied by altered sedimentary rocks and granite. The former occur in a belt ex-

tending along the lower valleys of the Running River and Oaky Creek as far as their junctions with the Burdekin. They are surrounded by granite on all sides, except on the west, where a newer series of sedimentary rocks overlies both them and the granite on the western side of the Burdekin River.

* "The country rock of the whole of the mining district (as exploited) consists of alternations of mica schists, talc-schists, greywacke, grits, conglomerates, quartzite, and limestones. The schists and quartzites are frequently interspersed with minute garnets, which are at times so numerous that for practical purposes I have designated them 'garnet rock.' The whole of these rocks are highly inclined, frequently vertically, and so much broken up by faults, that it is impossible to trace any individual bed for more than a few chains. Beds of limestones are met with along the south-west and north-east belt of mineralised country already referred to in a previous paragraph, as well as among the Mount Brown group of mines. These limestones have been traced for many miles ; the outcrops of the limestone show that they, as well as the 'adjacent sedimentary rocks' have been tilted up, contorted, and literally chopped up into pieces by faults, but also that the limestones themselves were originally isolated deposits, probably coral reefs.

"The limestone beds vary considerably in character, but all have suffered a great amount of alteration. The prevailing type is a white crystalline or saccharine marble. It is generally free of silica, but, on the other hand, some beds, having originally been charged with siliceous sand, now present little more than a skeleton of silica, the calcareous portions having yielded more to denudation. Sometimes, in the comparatively pure limestone or marble, the segregation of siliceous matter has formed a network of veins. In a limestone so highly metamorphosed it is not surprising that distinguishable organic remains are sought for in vain. I have indeed seen a few fossils which could be recognised as corals, although but slight traces of their outlines or structure were preserved.

"The age of the stratified rocks must for the present remain an unsettled question. Mr. Maitland doubtfully refers them to the 'Burdekin Bed' (Middle Devonian), believing them to be continuous with them, as they are developed lower down the Burdekin Valley, where they afford an abundance of characteristic fossils, as well as to be similar in lithological character. But it must be confessed that there is little evidence either for or against this view.

"The stratified rocks are pierced by masses, of limited extent, of intrusive acidic 'felstone,' or felspar and quartz-porphyry, a rock composed of orthoclase felspar with blebs of quartz."

Wherever the boundary between the granite and sedimentary rocks is well exposed, the intrusive nature of the granite, and consequently its later age, is made clear. A good example of this is seen on the left bank of the Running River, on the track between Ewan and the Macaulay Creek Mines. At this point a gully coming out from the granite hills exposes the upturned quartzites of the sedimentary beds in

* R. L. J., Brisbane, "The Kangaroo Hills Silver and Tin Mines," by authority, 1892.

contact with the granite, with tongues of the latter passing into them. The sedimentary beds are thus seen to be older than the granite, but further than this no evidence was forthcoming as to their stratigraphical position. The granite is perfectly normal in character, being composed for the most part of pink or white orthoclase with quartz and biotite mica. Intrusive dykes of diorite and also of eurite were observed at Macaulay Creek and Hidden Valley.

Tin Mining.—All the tin lodes at present being worked occur in granite country. The two main centres of prospecting are:—Firstly, the lodes in the neighbourhood of the proposed township of Kallanda, about 12 miles up Oaky Creek from the Burdekin River; and secondly, the lodes in the ranges at the sources of the Running River. The former comprise the properties of the Waverley, Planet, Kangaroo Hills, and Douglas Tin Mining Company, with various minor shows. The latter are still held by parties of working miners, having not yet reached the company stage. On one lode only has machinery as yet been employed, none of the workings being over 100 feet in depth.

* The year's record at *Kangaroo Hills* cannot be said to have been in any way eventful. The Waverley Company continue their policy of sub-leasing their mines and of opening their mill for the treatment of public stone on liberal terms.

For the last twenty years the mountainous country surrounding the head waters of the Annan River, some 30 miles south from *Cooktown*, has been the resort of the tin miner, and large quantities of tin have been won. The operations of the individual miner have, however, necessarily been confined to those creeks and gullies where water could be obtained, and attempts to develop the field on a more extensive scale have hitherto proved abortive. A powerful company, registered in Melbourne and in Queensland as the Annan River Tin Mines, No Liability, have now acquired some 400 acres of alluvial and lode ground in the neighbourhood of Mount Leswell. The success of the venture is largely dependent on the ability to secure an efficient water supply, and since November last the company have been actively engaged in constructing a race from Finlayson Creek to the mines, a distance of 7 miles, by which they hope to conduct water sufficient for sluicing purposes, and also for driving the battery that they mean to erect.

† Alluvial tin assaying 72 per cent., has been discovered on the Robertson River, about 40 miles south of Georgetown.

At the Majestic Claim, in the Townsville district, a tin lode has been found, 20 feet in width, assay £4 per ton, and another expected to bulk £3 per ton. There are also a couple of smaller lodes.

‡ The New Era, Northern Queensland, one of the lowest grade payable tin mines in the Commonwealth, the crushing stuff averaging only ·64 per cent. black tin, or about ·45 per cent. white metal. Yet a profit of £1,100 has been made out of 4,800 tons. The mine is owned mostly by the men at work in it.

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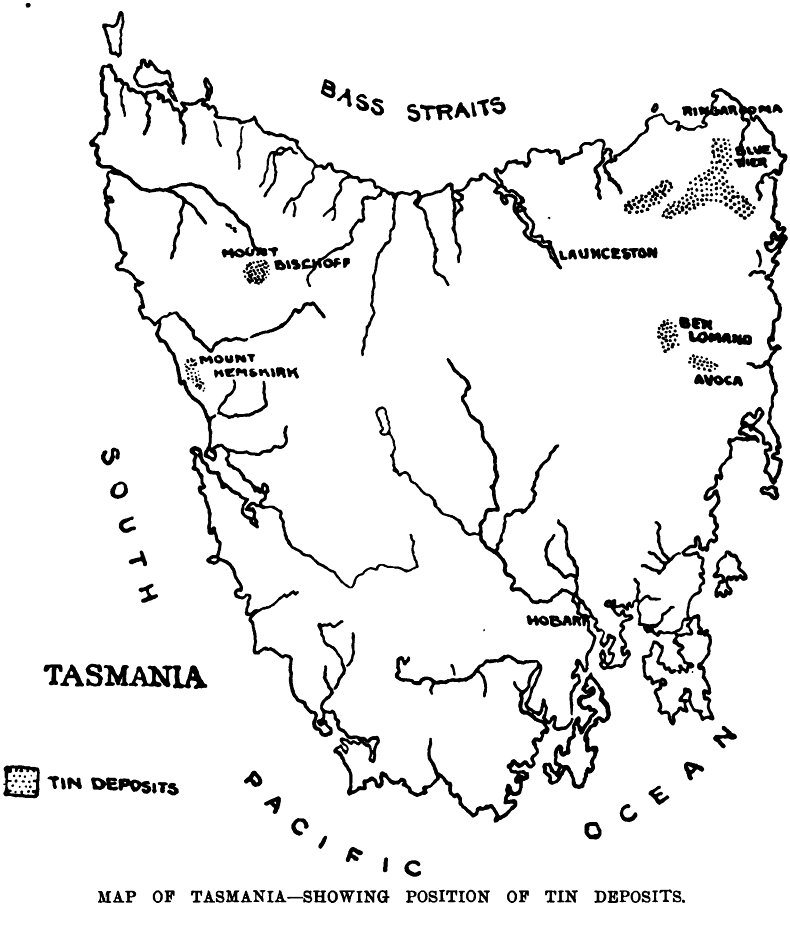
* Gov. Annual Report, 1905.
† "Mining Journal," Nov. 3, 1906.
‡ "Mining Journal," Oct. 27, 1906.



MAP OF TASMANIA—SHOWING POSITION OF TIN DEPOSITS.

CHAPTER IX.

TIN DEPOSITS OF TASMANIA.

THE tin deposits of Tasmania are situated in the north-eastern and north-western side of the island, with some comparatively unimportant deposits on the west and east coasts. The deposits of the most economical value are situated in the north-eastern portion of the island. Mr. W. H. Twelvetrees, the present Government Geologist, writes the following description of the Anchor Tin Mine and Blue Tier district :

"The granite of which the Tier is composed is that which, with textural and slight mineralogical variations, is the basement rock of the whole of the east coast of Tasmania. At the close of the Silurian period it consolidated upon intrusion, at great depths, into the Silurian slates and sandstones. The extent to which the latter have been metamorphosed and mineralised by the invading granite can be well studied along the zone of contact, near St. Helen's.

At the Tier it is a rather coarse-grained porphyritic granite, with large crystals of felspar, an inch in length, scattered through it ; grey, white, or pink in colour. Its mineral constituents are felspar, quartz, dark magnesian mica (biotite), and a little silvery potash mica (muscovite). Sometimes the white mica is quite absent ; its abundance seems to depend upon the presence of tin-ore. At George's Bay the granite contains a larger proportion of quartz and less felspar than upon the Tier. The first element to crystallise was the mica, then the felspar, finally the quartz. This is shown by crystals of mica occurring enclosed in the felspars, and by the residual silica filling the interstices or spaces between the well-formed crystals of felspar. So far, all are agreed. The differences of opinion begin when we consider the portion of the granite which carries the tin-ore. This is not so coarse as the ordinary granite ; it is more even-grained, and is not porphyritic. The dark mica goes through a series of changes into silvery and greenish-white mica, muscovite (non-pleochroic). The change is first into a dark bronzy mica, and finally, as the iron becomes gradually abstracted, into the white potash variety. This alteration can be observed under the microscope in one and the same crystal, which is partly iron-magnesia and partly potash. Often the felspar decays to kaolin, and the rock becomes softer, or there is extreme silicification, and the rock grows much harder. The magnesia liberated in the decomposition of the dark mica is re-deposited as talc, which gives a greenish tinge to much of the tin

granite; the felspathic material remains behind, to some extent, as kaolin. The new minerals developed in this variety of granite are cassiterite, wolframite, scheelite, fluorite, molybdenite, galena, copper pyrites. The iron pyrites may be original. No axinite has been yet found at the granite contact; this is no doubt owing to the absence of lime. Tourmaline is rare. Sapphires and topaz are found in the stanniferous gravels, and have probably been released from pegmatitic veins.

This tin-bearing granite has been labelled with different names, such as quartzose porphyrite, aplite, and, most frequently of all, quartz porphyry. Parts of the mass correspond with some of the tin-bearing granite at Altenburgh, in Saxony, called zwitter-rock, or stockwerk porphyry, only the latter usually has a good deal of topaz in it. Zwitter-rock is sometimes a greisen (quartz + mica), with very finely disseminated tin-ore; sometimes the mica is absent. The mica itself is a greenish fluoric potash-iron variety, which, together with topaz, has replaced the felspar. At other times the rock is nearly all quartz, and dark in colour, resembling the more quartzose varieties of the Blue Tier tin-granite. Typical zwitter-rock contains—quartz 50 per cent., mica 37 per cent., topaz 12 per cent., cassiterite 0·4 to 0·5 per cent. Varieties without mica consist of 70 per cent. to 71 per cent. quartz, 27 to 28 per cent. topaz, and 1·4 to 1·5 per cent. cassiterite. Zwitter is essentially a modified granite, resulting from a process of greisenisation which has started from cracks and fissures.

The most dyke-like occurrence which I saw was on Haley's Lease, on the old Blue Tier Company's ground, not far from Mr. Ogilvie's camp. In the race a dyke-like band of tinstone is exposed for a width of two chains, running through the porphyritic country granite, from which it is separated by a small pegmatitic vein. Further east a smaller band of soft tinstone, 1 foot wide, traverses the granite, and has quite sharply defined boundaries. Still further east, a wider vein of tinstone is seen, also separated from granite by a pegmatitic facing. I have alluded to this stanniferous variety of granite as tinstone, but am not sure that it is the best term, as it is also used elsewhere for cassiterite, the ore of tin. The above occurrences cannot be considered as conclusive, for they are associated with pegmatic veins, which may have been the mineralising channels.

The two strongest objections to the dyke theory are:—

1. The irregular boundaries of the tin-bearing granite;
2. Its occurrence in the form of floors.

At the Anchor mine it disappears to the north and east under a capping of country dark mica granite, a very singular thing if it is a dyke. To the north-west and west the Anchor stone extends to the Crystal Creek, passing under some country granite on the east side of the road bridge; then, west of the creek, the altered granite, at first non-stanniferous, and then tin-bearing, continues west through the tin properties of the Crystal Hill and Liberator Companies, merging into ordinary country granite at the Working Miners' Creek, on the western boundary of the Liberator. Again, from the Crystal Hill, a narrow strip of tin granite

extends at right angles to its previous direction, due north through the Australian sections and Haley's Lease, across the Wyniford to Beales' sections at Mount Michael, spreading out like a fan as it approaches the Wyniford, and, apparently, connecting with the Moon property on the east. In the middle of the Crystal Hill sections, some of the unaltered country granite has survived. The irregularity of the contour of the formation seems irreconcilable with a dyke origin, and, in addition, the general structure of the stone differs from that of elvan dykes. The latter are generally coarsest in the middle, and finer grained near the sides.

Apart from elvans, wide granite dykes often traverse granite masses, but in the present case there is no parallelism of the sides of the formation —no walls, nor anything to suggest that the tinstone is the filling of a fissure.

There is a very striking indication of floors in the Anchor Mine. The tinstone in the old eastern workings lies under the barren country granite, which ascends the hill thence to Lottah (see Fig. 22); a flat

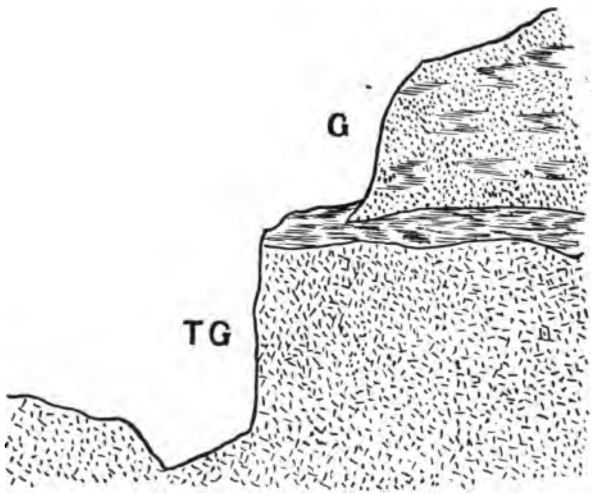


FIG. 22.—*G.* Granite. *T.G.* Tin granite.

seam of quartz and bronzy mica, with a few large felspars, forms a horizontal floor separating the tin-bearing stone below from the coarse (here decomposed) granite above. A face of about 30 feet of the latter is exposed at this bench. Just below the seam is some white quartz and coarse tin, and, within 6 inches of it, I noticed a large felspar crystal quite enclosed in the tinstone; this was evidently due to the influence of the dividing seam. We have here a good example of a horizontal boundary or floor. Practically the same phenomenon is repeated in the top workings of the mine, where dark mica granite rests upon the tinstone, and has to be stripped before the latter can be worked. This

granite overburden may be expected to decrease towards the west, and increase towards the east. I infer this from the fact that the modified stone rises about 400 feet to the road in a north-westerly direction, while northwards it is hidden beneath the huge granite mass which ascends from Lottah to Poimena. On Haley's Lease, at the old McGough's tunnel-pit, 1,400 feet above the Anchor face, the country granite (also decomposed) occurs overlying the tin-rock, as shown in Fig. 23.

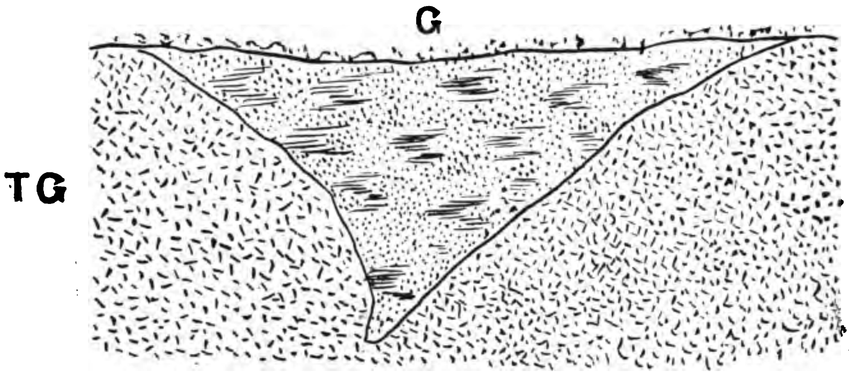


FIG. 23.—*G.* Granite. *TG.* Tin granite.

Dykes.—There are a few dykes of eruptive rock, which traverse the granite. These are basic, and have usually been taken for Tertiary basalt, which they greatly resemble. Microscopical examination shows them to be dykes of diabase. [Constituents = plagioclase felspar + augite, the latter being greatly chloritised : structure = diabasic. No olivine.] There is a dyke of this kind, about 50 feet wide, in the granite, crossing the road S. of Lottah at the Horseshoe bend, between Lottah and the Anchor manager's house, and said to be traceable eastwards for 3 or 4 miles. Stones belonging to the same dyke are seen on the track near the office at the Anchor Mine.

I saw a wide dyke of similar stone on Haley's Lease, a little north of Ogilvie's camp. There is another one on the Lease about 30 chains further north. These dykes are all roughly parallel, taking a N.E.-S.W. direction. They are of Mesozoic age, consequently younger than the deposits of tin-ore, and have no bearing whatever upon its deposition.

Distribution and Grade of Ore.—The quality of the tin-ore from the Blue Tier mines is excellent. The average of the whole district is about 72 per cent., some of the produce reaching a higher figure. The ore is remarkably free from iron ; in some of it, however, traces of copper are present.

There seems to be no rule for making use of the distribution of the ore in the tin-granite (*Germ.* Zinngranit). I could see nothing to show whether the tin has been concentrated in the middle of the formation more than towards the margins, or *vice versa.* The patches are quite

irregular, and will, I believe, be found to be more dependent upon the natural fissuring of the rock than upon any law of segregation. In some places the stone is rich and heavy ; elsewhere, practically barren. Taking the formation as a whole, the probabilities are that the ore contents will range from a shade under $\frac{3}{8}$ to about $\frac{5}{8}$ per cent. black tin. An average of $\frac{1}{2}$ per cent. ought to be expected from most of the mines.

The percentages ruling at the different mines are :—At the Anchor, about $\frac{3}{8}$ per cent., passing all stone through the mill ; Australian, $\frac{3}{4}$ to nearly 1 per cent. ; Liberator ranges from $\frac{1}{2}$ to nearly 1 per cent., averages $\frac{5}{8}$ to $\frac{3}{4}$ per cent. ; Haley's Lease used to yield $\frac{2}{3}$ per cent. ; the Moon, $\frac{3}{4}$ to $1\frac{1}{4}$ per cent. At the new Crystal Hill Mine, now being opened out, I took samples from each face indiscriminately, without picking or seeing whether any tin was visible or not, and the total assay was 0·6 per cent. metallic tin, or (at 70 per cent.) 0·85 tin-ore. Large deposits of $\frac{3}{4}$ per cent. stone undoubtedly exist, but then, again, poorer areas come in to reduce the average, which from all appearances is in the neighbourhood of $\frac{1}{2}$ per cent., taking the Tier as a whole.

The Anchor stone appears to be the lowest on the list, and in the district it is generally considered the poorest stuff. I fancy this is largely owing to the fact that the mine is being operated upon a large scale, and that the stone is not selected, but broken down from the faces and passed through the battery just as it comes. It is certain that if the other mines commenced to clear away the whole of their formation without selecting promising places at which to attack the deposit, the per cent. yield would be somewhat reduced.

Anchor Mine.

This is the most important and best equipped mine in the district. It is situated just to the S.W. of Lottah, on the slope of the hill above the Groom River. It was reported upon by Mr. Thureau in 1886, and again by Mr. Montgomery in 1889 and 1893. Work has been carried on here for over 20 years intermittently, but until the present management took the mine in hand imperfect and costly methods had been the rule. Prior to the end of 1892, 30,734 tons were crushed, returning 288 tons tin-ore, equal to 0·937 per cent., but with work on a larger scale the average yield of the stone has decreased. For the 21 months ending June 1901, 111,167 tons stone have been crushed for 434 tons tin-ore, equal to 0·39 per cent. The company's ground covers 315 acres, but the actual work of winning ore is, so far, confined to an area of about 12 chains square, which is being slowly enlarged as the upper face advances north into the hill. The formation, or matrix, of the ore is the tin-granite described above. Generally, the felspar of the granite has not been wholly removed, and the rock is not very hard. In the Pentridge face, however, the rock is quartzose and excessively hard ; so hard that it has been taken for lode-stuff. It belongs, however, to the same formation as the other. This eastern face carries good stone, of a quality near 1 per cent. Twelve feet below it 100 tons of tin-stone were taken

out by Mr. Mitchell, yielding 2 per cent. tin-ore. A tunnel has been driven 150 feet into this hard rock, and 75 tons of stone, taken out for a trial, gave 1 per cent. tin-ore.

The faces now being worked are 10 or 12 chains west of the above workings, and extend up the hill for a vertical distance of about 200 feet. No. 1, the lower face, forms a crescent 300 feet in length by 55 feet in height. The whole of the rock is broken down and trucked to the stone-breaker without selection, for all of it contains tin. Green mica and talc give a greenish tinge to the rock. A little fluorspar accompanies quartz leaders ; no bismuth or galena has been observed, only a little copper pyrites. Special concentrations of ore may be seen in floors of the greisenised rock and in nests. The principal joints and seams run E.W. and N.S. ; minor ones traverse the rock in all directions. Tin is always looked for in and near the seams.

No. 2 face is about 150 feet above No. 1, and No. 3 is 50 feet above No. 2. I ought to say that 35 feet below No. 1 a tunnel has been driven for 250 feet, and 50 tons of stone were taken out and raised by horse-power to the stone-breaks, and returned a good yield at the battery. It may be added that in the No. 1 face the stone on the whole keeps the same in quality from top to bottom, with, of course, richer and poorer patches occasionally.

No. 3, the uppermost face, has more stripping than the others, and the tin formation is covered by about 18 feet of country-granite, of which there is only a little in the N.W. corner of No. 2 face, and none at all lower down in No. 1 face. The tinstone in the upper face is of the usual character, except that it carries more leaders of stanniferous quartz.

A new epoch in the history of the mine commenced when the present general manager, Mr. R. Mitchell, took charge of the work, and re-adjusted the dressing plant. New faces were opened, and the property was prospected, both by tunnels and boring, with the diamond-drill. In 1899 nine bores were put down, five of which are in advance of No. 1 face, three being near the old eastern workings, and No. 9 600 feet further north. As a general result the bores show that the rock is variable as a tin-carrier.

The dressing sheds contain two 50-head batteries, with 1,000 lbs. stamps and accompanying classifiers, jigs, vanners, settlers, and buddles ; the dressing is automatic and efficient. With full water supply, the 100-stamps will crush 100,000 tons of stone a year ; but, unfortunately, for want of water, the 100-head have never run for long continuously, and the average number running last year was only 34. The management claims that when in full work the ore can be raised and treated for 2*s*. 6*d*. per ton of stone. The average hands on the pay-list for the past twelve months have been 112, and for full work not more than about 30 additional would be required. It is easy to see how desirable it is to obtain water-power sufficient for driving the complete plant.

The company have water-rights for 48 head, and if that amount of water could be obtained, there would be no difficulty in driving the whole of the crushing and dressing plant. The new race, when com-

pleted, will extend 39 miles to the South George River; the first section goes 26 miles to the North George, tapping Waratah Creek, etc. on the way, and the remaining 13 miles to the South George will be constructed subsequently.

Assuming the grade of ore to continue, and it seems safe to do this, the quantities necessary for success may be reasonably considered as existing. The ground for some depth below the lowest face and between the lowest and the top faces has been proved by the diamond-drill to be tin-bearing. Of course, in this area there are poor patches as well as good ones, but there is no doubt of the tin-bearing formation existing continuously north and south between the faces for a total horizontal distance of 8 chains, and I think it may be legitimately accepted that the per cent. value of the stone for that distance will not be less than that shown by the battery returns the last few years, viz., 0·39 per cent. The width of the formation has been proved for about 12 chains, but there is a good deal of broken ground, and, in my calculation of quantities which may be reckoned upon, I have confined myself to the width of the present workings, viz., 4 chains, leaving on one side the eastern ground, the value of which cannot be easily estimated. The eastern ground will probably swell the total output. The proved block of stone to be taken out will then measure 8 chains long by 4 chains wide by 0 to 200 feet high, which (with a sp. gr. $2{\cdot}67 \times 62{\cdot}425 = 166{\cdot}67$ lbs. per cubic foot) will total 1,037,142 tons, or, allowing 20 per cent. for barren interspaces, 829,714 tons tin-bearing stone. This quantity will suffice to feed 100-head of stamps continuously for eight years, and the tin-ore contents at 0·309 per cent. would be 2,563 tons. This output can be increased by the produce of the eastern workings, but most of all by the advance of the faces into the hill north of the present upper workings. The eastern workings cannot be extended far to the east without coming under a heavy cap of country-granite; still, the ground explored up to date there will give a large output. Again, in the principal workings every additional chain of width taken in the face means nearly 200,000 tons more of material, or a couple of years' more work between the levels of existing faces.

A question of interest is whether the tin-granite will rise with the hill, or the overburden of barren granite increase as the work advances. From my examination of the country surrounding the workings, I am led to believe that the overburden will be heavier east and north of the present works, but that it will decrease towards the west and north-west. Tin-granite is seen on the road north-west of the mine and 500 feet above the lowest face, and I believe the future development of the mine will disclose a continuous vertical section of 500 feet; but whether it will all be payable stone cannot be ascertained beforehand, except partially by use of the diamond-drill. The tunnel below the lowest face has also shown that very good tin-bearing stone is going underfoot. The full quantity of stanniferous rock existing on the property cannot be estimated without making assumptions unverifiable in the present stage of development. It is not known, for instance, how far the percentage of tin may fall in the zones of rock which have not

yet been proved; and, without further boring, it is not absolutely certain that concealed floors of barren granite may not interrupt the continuity of the formation here and there. But if, after extending the present faces right across the property, the ground throughout proves good enough to send to the battery, then I estimate there is stone enough on the company's sections to keep the mill going continuously for between 40 and 50 years.

ANCHOR TIN MINES.

	Stamp working.	Tons crushed.	Yield Black Tin. Tons.	Cwt.	Cost per ton. *s.*	*d.*
June 30, 1899 -	46	38·179	131	0	3	10
„ 1900 -	38	40·838	152	15	5	5
„ 1901 -	33	38·190	140	16	5	11
„ 1902 -	43	41·530	146	5	5	2
May 13, 1904 -	76	108·529	258	3	3	5
June 30, 1904 -	91	136·655	243	13	2	10
„ 1905 -	74	118·634	190	7	2	5

The Tin deposits of the Ben Lomond District were at one time extensively worked. The following account of the geology of this district is taken from the Government Geological Survey of 1901 :—

"Ben Lomond is situated about 14 miles north-west of Avoca, and the mining district lies to the south of the mountain. The general geology of the district is, with the exception of some of the occurrences of the greenstone and Mesozoic strata (which do not affect the mining industry in this district) very simple.

"The bedrock of the district is granite of Devonian age. This rock solidified under a probably massive covering of Silurian sedimentary rocks—slates, sandstones, etc.—but these have long ago been removed over the greater part of the district. Remnants, however, remain in several places, especially in the eastern and north-eastern parts of the field, where, in the vicinity of Storey's Creek, a considerable area is still covered by Silurian strata. These rocks are also found in the north-western portion of the field, and further south very small isolated patches are sometimes encountered on the summits of the highest ridges. The denudation and removal of the Silurian strata must have taken place during the later portion of the Devonian period, for, lying on the top of the granite, and often covering the remnants of Silurian strata, we find horizontal beds belonging to the Permo-carboniferous period. These have, however, also been very largely denuded, and in the southern portion of the field are for the most part confined to the tops of the granite spurs, where the harder grits and sandstones have resisted denudation and have protected the softer or more easily decomposed granite underneath. Much of the northern portion of the field is overlaid by quite a thin layer of Permo-carboniferous strata, and through this the granite outcrops frequently. Further north, on the slopes of the mountain itself, the carboniferous strata increase in thickness until the perpendicular cliffs of columnar

greenstone which form the massive capping of the mountain are reached. The contact, however, of the columnar greenstone and the Permo-carboniferous rocks is obscured by a heavy talus of greenstone blocks fallen from the mountain. Next to the Permo-carboniferous strata in question of age are the Mesozoic strata, which are mentioned by Mr. Montgomery * as occurring on the mountain at an elevation of 4,000 feet above sea-level, and overlying the greenstone. I found typical felspathic sandstone of Mesozoic age in the valley of Gipp's Creek, at an elevation of only 1,400 feet, apparently underlying the greenstone. These rocks are exposed in steep cliffs, rising up on the western side of the creek for a height of about 200 feet. Above these there are, perhaps, 500 feet of columnar greenstone. The dip of sandstone is about 15° or 20° to the south-west. On the eastern side of the creek we find horizontal Permo-carboniferous sandstones resting on the granite.

"The eruption of greenstone took place towards the end of the Mesozoic period, as has been proved in other parts of the State. Its relation to the Permo-carboniferous and Mesozoic strata are extremely various and perplexing, sometimes overlying, sometimes underlying, and sometimes breaking through these rocks.

"The majority of the granites in which the deposits of tin ore occur are composed essentially of felspar and quartz, there being very little mica present. Much of the felspar (*orthoclase*) occurs in fine large crystals of the Carlsbad twin type, distributed porphyritically through the ground-mass of the granite, which is composed of a finer-grained but thoroughly granular mixture of quartz and felspar. In many places a rock very much finer grained than the granite, but composed of the same constituents, is to be seen. Only once did I observe this rock *in situ*, and then it formed a small dyke in the granite. It is probable that the other occurrences are of the same nature. Quartz porphyry also occurs, sometimes forming the margin of the granite mass, but at other times possibly forming dykes in the granite. One interesting occurrence is to be seen on the old Republic Mine, where a quartz porphyry occurs with perfect double-ended crystals of quartz distributed through it. The granite is traversed by numerous veins of pegmatite, varying very largely in composition; occasionally they are found composed mainly of giant crystals of quartz, felspar, and mica, with needles of tourmaline, and in one conspicuous instance with very large crystals (up to 2½ inches in diameter, and 5 or 6 or even 10 inches in length) of beryl embedded in the quartz. Mr. W. H. Twelvetrees has examined thin sections of this beryl under the microscope, and has proved the presence of minute enclosures of liquid carbonic acid, proving that the mineral has been deposited under conditions of very high pressure. The pegmatite veins very frequently contain tin ore, and in one case—the old Lomond Mine—extremely rich patches of tin ore were found in a small vein of pegmatite. A very small proportion of the tin is found in the veins themselves; it is found very much more

* Report on the Ben Lomond District, May 5, 1892.

abundantly in the rock on either side of the veins, and very often the vein is so small and so insignificant, in comparison with the impregnation which has taken place from it, that it may very easily escape notice altogether. The typical tinstone of the district occurs as a hard, highly quartzose granular rock, seldom containing true mica, but frequently a massive mineral of almost the same composition, locally called porphyry, steatite, talc, etc., but really, I think, being a variation of one of those massive muscovites which have been grouped together under the general name of pinite. Chlorite is also almost always present, even in the hardest portions of the stone. Tourmaline occurs sometimes in large quantities, but more often in the normal tinstone it is absent. Fluorspar is apparently always present; it occurs somewhat sparingly as the filling of small veinlets running through the stone, though occasionally it is met with in larger masses. Of the metallic constituents, tin oxide (cassiterite) is the most abundant, and the only one of commercial importance. It occurs in fine grains and crystals throughout the stone. Besides this, we find in small quantities blebs of galena, black zincblende (marmatite), chalcopyrite, arsenopyrite, and pyrite, distributed through the stone. These minerals also occur in small irregular veins and patches, and one case is recorded in which a considerable mass of argentiferous galena, assaying 80 oz. of silver to the ton, was found in the tinstone at the surface. The component minerals are not evenly distributed throughout the tinstone; often it is composed entirely of granular quartz, and, as a rule, quartz is very much more abundant than any other mineral. After quartz, chlorite is the most regular constituent. Pinite occurs sometimes distributed evenly through the stone, at other times in irregular patches, in which case it is often highly tin-bearing. Topaz is apparently absent. Genetically, the tinstone is closely allied to greisen, but as mica is absent I think it advisable to retain the miner's term, tinstone. The German miner has the convenient term 'zwitter' for such stone, but I am not aware of any English equivalent. The term tinstone must not be taken to imply that tin is necessarily present in payable quantities. I believe it will always be found to contain some tin, but the tin content may fall so low as to become practically indeterminable by ordinary methods.

"The boundary between the tinstone and the granite is not marked by any defined wall; there is rather a passing over from the one to the other, though this cannot be said to be gradual, since it takes place within the space of a few inches. The stone in the vicinity of the granite is apparently always poor in tin. From the nature of the boundary existing between the two rocks only one conclusion can be arrived at, namely, that the tinstone is a product of the alteration of the granite. This conclusion is abundantly demonstrated by an examination of the mineralogical and structural character of the tin-stone."

Mount Rex.

Mount Rex Tin Mine, about five miles N.W. of Avoca, is the most important mine in the Ben Lomond district.

The mine is situated near the boundary of the granite and greenstone. Towards the north the granite is overlaid by horizontal layers of granite wash and sandstones of Permo-carboniferous age.

The granite is composed chiefly of quartz and felspar, with the latter often developed in large crystals. Several tin-bearing formations are known on the Company's sections, the most important at present operated on is about centre of Section 1191–87 M. It consists of a large mass or chimney of tinstone from 60 to 80 feet in diameter.

The shape of this deposit is very irregular, and the horizontal section shows it is very different at the two levels. It has an approximate strike of north and south ; at the upper level it is a little west of north, and the lower level a little east of north. The general strike of all the tin lodes in the district is west of north.

Small quartz veins traverse the ore body with a general strike west of north, and small veins of fluorspar run through the stone having no defined strike. This deposit may be regarded as a lens-shaped zone of impregnation in the altered granite. Besides tin the ore contains a little galena, copper and iron pyrites, and zinc-blende. This ore requires calcining, and the presence of a small amount of lead constitutes a considerable metallurgical difficulty.

This deposit is of an unusual character, and the method adopted for working the same is of interest. A large chamber has been excavated at the 80-feet level, and the ore taken out here averaged about 7 per cent. of black tin ore. A shaft has been sunk south-east of the deposits to a depth of 142 feet, and a cross-cut has been driven across the deposit, which is over 74 feet wide at this point.

The tin contents are by no means uniform, rich bands and patches occurring besides poor ones: the bulk of the tin is contained in the hard quartzose tinstone ; the same sort of ore has been worked by the Great Republic Mines, about 2 miles north-west, to a depth of 450 feet, and there seems no evidence why the ore shoots should not live to great depths in the district.

In the upper portion of the Mount Rex deposit a considerable quantity of galena was found. This galena was probably of secondary origin, and the percentage of galena has decreased as depth has been attained.

About 7 chains north of No. 1 deposit another tinstone formation is exposed, the ore being of the same nature as the first ore deposit described above, and presenting many similar features. There are several other ore bodies on which not sufficient work has yet been done to completely determine their commercial value.

The Company has erected a 20-head battery and complete concentrating and calcining plant. The stamps have a weight of 1,100 lbs., crushing to 14 mesh ; the pulp passes through a pair of spitzlutens. The former are treated in two compartment jigs, and the latter, after further classification in spitzkastens, are treated on Wilfley tables. The whole of the tailings pass over Munday's concave buddles, and the slimes are treated in the usual way by settling pits and frames.

The zinc and the copper present in the ore are leached by means of

dilute sulphuric acid. Lead, however, owing to the insolubility of the sulphate, cannot be got rid of by this method.

Tin Deposits in the Avoca Tin-Mining District.

There has been a considerable amount of mining done in this district, the alluvial deposits being of secondary importance to the lodes.

To the south in the valley of St. Paul's River the geological structure of the country is rather complex; numerous dykes of diabase greenstone occur cutting through the older granites and Permo-carboniferous formations. Immediately beneath the greenstones, near the St. Paul's Dome come the sandstones, mudstones and conglomerates of the coal measures, which appear almost to completely surround the Fingal Tier and in places carry seams of coal. Mr. A. Montgomery, in his Geological Report to the Government in 1892 of this district, states that tin ore exists in coal measures.

This interesting fact is given in the following account:—"On a Spur to the west of Bayley's Marsh Creek the ridge of granite is crowned with huge castellated blocks of Permo-carboniferous grits and conglomerates, 400 to 500 feet above the marsh. The lowest layers of these beds resting upon granite is a boulder conglomerate containing water-worn lumps of granite and quartz, and amongst these very much water-worn tin-ore has been found. This is one of the oldest deposits of alluvial tin that has been recorded within my knowledge. It goes far to show that the tin lodes existed in the granite formations even in Palæozoic times, before the conglomerates were laid down as beds of boulders, by the water of the Permo-carboniferous sea."

The Brookstead property near the St. Paul's Dome is traversed by a number of tin-bearing lodes running W.N.W. and E.S.E.

The lode stuff is as a rule mainly composed of quartz, but a great deal of tourmaline is also commonly present; there is also more or less mica, talc and kaolin in the quartz, and fluorspar is not uncommon. Some of the outcrops are stained with oxide of iron. Tin ore occurs in bunches and strings, and also impregnated through the veinstone, often in fairly large crystals, but more commonly in pieces from the size of a pea downwards.

The Brookstead Proprietary Company has done some development work on these lodes and erected a small crushing and dressing plant, but the result has not yet been up to expectations. A certain amount of alluvial tin has been won from the small valleys in the hills facing the St. Paul's river on the north, and there is possibly some payable alluvial wash in the flats near the river which may repay the expense of dredging.

The Roys Hill Tin Mine, near the Brookstead estate, consists of a greisenised zone forming the margin of a small granite spur which rises out of the Silurian strata; the tin deposit here is of a distinctly patchy character. Both here and at the Brookstead estate, work has been carried on intermittently for want of sufficient capital.

OVERBURDEN AT BROTHER'S HOME No. 1 TIN MINE.

Description of Briseis Tin Mine.

The Briseis Tin Mine, Ltd., and Brother's Home No. 1, are the most important mines operating on the deep-lead near the Ringarooma River. They have an area of about 200 acres east of the present Ringarooma River at what is practically the head of the lead.

The early history of these workings is somewhat interesting. The lead was discovered and worked in 1872 by a party of miners, the shallow alluvial proving highly payable, the necessary water being obtained from the Cascade River; the lead, however, proving of greater extent than first anticipated, two other companies subsequently started mining operations.

This part of the lead from the engineer's standpoint must be regarded as a whole, and the trial for many years to work it by three separate companies caused difficulties and constant litigation. It was only recently that the Briseis Company acquired by purchase and arrangement the working control of the whole area.

The overburden, according to Mr. W. H. Twelvetrees, is an olivine basalt, in which the felspar is mostly porphyritic, and the ground mass largely consists of small brownish crystals of augite. In some places this has been subjected to decomposition, which produces a soapy material containing some hard boulders. These vary in quantity in different parts—from 25 to 50 per cent. of the whole, and in size from that of road metal up to boulders of two or three tons in weight. In the highest part of the Briseis Hill there occurs a hard core of solid columnar basalt, the various layers of which have been used for paving the water races.

The following particulars were given to author by Messrs. Lake and Currie, Engineers to the Briseis Company :—

In March, 1903, it was estimated that on the joint properties there remained unworked 4,200,000 cubic yards of tin-bearing drift, which was covered under 2,181,000 cubic yards of overburden.

The local water supply having proved quite insufficient to handle economically such a vast quantity of material, the Briseis Company had constructed a race for the purpose of bringing water for a distance of over 30 miles. Some idea of the size of this race can be obtained from the fact that since its completion it has delivered at the mine approximately 24,000,000 gallons of water every day.

The Briseis Company have two other local supplies of water, but the quantity obtained from these varies within wide limits, according to the rainfall.

Before it is possible to work the drifts to the best advantage, it is necessary that the overburden should be completely stripped for a considerable distance ahead of the working faces. It is to this work that all the resources of the Briseis Company have as yet been devoted, only a sufficient quantity of drift being sluiced to slightly more than cover the Company's total outlays and expenditure.

Description of the Overburden.—This consists of two layers separated by a bed of drift, which in most cases carries a little tin ore. The top layer consists generally of basaltic soil containing hard basaltic boulders, while at two points masses of solid columnar basalt occur. These form

the caps of two hills, which are both being removed bodily, in order to uncover the drifts lying below. The greater proportion of this overburden can be removed by water, but the rock and larger stones must be removed by trucking.

Method of removing Overburden.—This is accomplished in the following manner :—

In order to under-cut the harder material and cause it to fall, and thus become more amenable to disintegration, about 20 feet of the top drift is removed along with it. The softer material and smaller stones are gradually washed away through main and branch tail races kept as close up to the faces as possible, while the larger blocks and stones are allowed to accumulate until they destroy the efficiency of the water. The nozzles are then diverted to other faces, while the accumulations of stones are removed by trucking, for which purpose main and branch tram-roads are also laid close up under the faces.

Nature of the Drift.—This consists mainly of coarse quartz sand, generally white, although occasionally of a red colour. The drift is generally very clean and easily removed, but in places bands of a stiff pug occur, which cause a little trouble. This pug contains no tin, and requires to be broken up and in some cases removed by hand. There also occurs in places what is known as ferruginous cement. This consists simply of drift cemented together by the infiltration of water carrying iron in solution. The cement in places carries tin, but the quantity depends entirely on the amount of tin in the drift before the solidification took place. When the cement is found in rich drift it is probably rich, and when in poor ground there is no reason why it should be richer than the surrounding drift. The tin ore occurs in irregular bands or layers of varying thickness. In places it is very nearly barren, and in other places rich streaks of pure cassiterite occur. Generally speaking, it may be accepted that all the drift contains a certain amount of tin, but that the richness increases with depth until in the actual gutter of the lead a very high percentage of black tin is found to occur. From the peculiar nature of the deposit, it is impossible to estimate what the average value of the drift will prove to be, or what total quantity of tin is likely to be recovered. From past results, it would seem that a yield of from 5 to 10 lbs. per cubic yard may be reasonably expected, but it has now been clearly demonstrated that even a less yield can be worked with a large margin of profit.

Method of working the Drifts.—These are worked entirely by hydraulic methods. The drift is first washed down through ground sluices, where all the tin contents are caught, while the lighter material is washed away. When it is thought that a sufficient amount of tin has been concentrated in any particular ground sluice, this is gradually worked down to the sluice boxes and streaming sheds, where the tin, which occurs in comparatively coarse grains, is easily separated from the accompanying material. There are fortunately no troublesome impurities, and an average product containing 75·45 per cent. metallic tin is obtained by this simple process. A considerable portion of the richer drifts lie below the actual sluicing level, which is regulated by the outlet

VIEW OF THE WORKINGS, BRISEIS TIN MINE.

of the Ringarooma River. Such drifts are raised to the necessary level by means of hydraulic elevators.

The following figures, which are the actual results obtained during the first eight months of 1904, will give a clear idea of what is being accomplished :—

During the period an average volume of 36,000,000 gallons of water was delivered at the mine from the various races : a total quantity of 495,277 cubic yards of overburden was removed, of which approximately 13½ per cent. was solid matter, which had to be removed by trucking. The average cost of this work, including all labour, stores and materials, was 5·3*d.* per cubic yard, or, including the proportion of all general expenses, salaries and administration, 6·48*d.* per cubic yard. The total quantity of drift sluiced during the period was 102,440 cubic yards, from which 281 tons 12 cwt. of black tin were recovered, or 6·1 lbs. per cubic yard sluiced. The black tin produced 206 tons 17 cwt. of metal, equal to 75·45 per cent. The cost per cubic yard sluiced, including all expenditure up to bagging the black tin in the tin-shed, was 6·65*d.* per cubic yard, or £10 1*s.* per ton of black tin.

The Briseis mine produced 971 tons in 1905, as against 422 tons in 1904, showing an inclusive average yield per cubic yard shifted for the first nine months of 1·94 lbs.

During the period the overburden removed has been the heaviest and most solid on the property, while the confined nature of the sluicing faces would not permit of the most economical work being accomplished.

In the Blue Tier, Tasmania district, there is a deep alluvial lead locally known as Thureau's Deep Lead. The country rock from George's Bay, the coastal port for this district to the Blue Tier, is all granite except in one portion on the east where some slates and sandstone of Silurian age occur. Except for this sedimentary strata, the lead is entirely bounded by granite which crops up along both sides at various intervals.

This deep lead is the old bed of the George's River in early Tertiary times ; the western part of Tasmania must have been higher above the sea level than now, and the bottom of this deep lead is probably 100 feet below the present sea level ; the Blue Tier Range must then have been higher than it is now, as denuding agents have been at work wearing it down unceasingly ever since, and the modern river valleys are probably very much below the level at which the streams ran that carried out the channel of the lead.

A great deal of work has been done on the surface, and some good shallow alluvial mined, but no attempt has been made to work the deep alluvial gutter that must exist in some portion of the lead. This would require to be tested thoroughly by bore-holes before any extensive scheme be undertaken, and it is doubtful if the superficial portions of the lead could be profitably worked by hydraulic sluicing even on a large scale.

Heemskirk District—West Coast Tasmania. The chief mine here is the Mayne Tin Mine.

The country-rock consists of Silurian sandstones and slates, traversed in many places by quartz-tourmaline veins, which have hardened and

tourmalinised the strata in their vicinity. The contact of the Silurian strata with the main mass of granite is situated some 20 chains north of the section.

Tin ore was first found on the surface of the spur in the form of floating nuggets. These soon led to the discovery that much of the surface-soil and rubble was rich in tin, and eventually the source of the tin was located by the exposure of the outcrops of several lode-formations. This is worked on a small scale. December quarter, 1905, 10 men turned out 11 tons of tin ore.

The Mount Bischoff Tin Mine is described in Chapter XV.

CHAPTER X.

TIN DEPOSITS OF WESTERN AUSTRALIA, NORTHERN TERRITORY OF SOUTH AUSTRALIA, NEW ZEALAND, AND VICTORIA.

Tin Deposits of Western Australia.

Tin (alluvial and lode) has been discovered in three widely separated localities in this colony, viz., at the head of the Bow and Lennard rivers, in the Kimberley district, at Brockman's Soak in the Pilbarra district, and at Greenbushes in the south-western portion of the Colony.

The last-named field is a comparatively recent discovery, and far exceeds in value any other tin fields yet known in Western Australia.

The Greenbushes Tinfield, as defined by the authorities, is situated on a fairly lofty tableland drained by the heads of Norrilup and Hester's Brook. The highest point of this tableland is 900 feet above sea level, and is crossed by the main road from Bridgetown to Donnybrook. The surface of this tableland is hilly and broken, but to the south-westward the creeks open out into large swampy flats, which are drained by steep rocky channels into the Blackwood River. The field is connected with the main railway system of the Colony. Tin-mining in the Kimberley and Pilbarra (Marble Bar) districts has only been carried out in a desultory manner, the climatic and other conditions being very adverse to the undertaking of mining operations on a large scale, and very few details are available. In the author's opinion there is a very great future for tin-mining in these districts, but the scarcity of water presents grave difficulties. Even on the Greenbushes field in the south-west, where there is a good annual rainfall, water is none too plentiful at certain seasons of the year, and operations are retarded in consequence.

The value of the output of black tin for the year 1902 (the last return available) was £39,783, the two producing districts being

Greenbushes and Pilbarra. This return must be considered highly satisfactory in view of the facts that in 1889 the estimated value of the ore exported was only £300, and that at the present moment, owing to the wonderful gold discoveries of recent years, the tin-mining industry has been more or less neglected. Nevertheless, there is a future for tin-mining in this Colony.

The tin deposits of Greenbushes fall naturally into two distinct categories :—

Superficial deposits :—
(*a*) Alluvial deposits.
(*b*) Residuary sand gravels, etc.

Deposits in country rock :—
(*c*) Tin-bearing granite.
(*d*) Tin-bearing dykes.

Alluvial Deposits.—These are found flanking the course of all the existing watercourses. The alluviums do not attain any very great thickness, but a fairly large proportion of tin has been derived from these deposits. The whole of these modern alluviums are not tin-bearing ; the richest seems to be that formed by Spring Gully and its tributaries, where a great deal of work has been accomplished. The deposit in Spring Gully consists of two distinct portions :—

(1) An upper, or "free dirt," *i.e.* loose gravel ; and
(2) A lower, stiff, "clayey dirt," containing irregular bands of detrital tin.

The free dirt, which varied from 1 to 3 feet in thickness and about 18 to 20 yards in width, proved exceptionally rich in tin. The physical character of some of the tin shows that it can only have been released from the parent rock in close proximity to where it is at present found. No small portion of it has been derived from the denudation of the granite belt, reticulated with tin-bearing veins, which crosses Spring Gully from north to south.

Residuary Sands, Gravels, etc.—In addition to the alluvial deposits, by far the larger portion of the field is covered with a mantle of variable thickness of sands, gravel, and conglomerate. These deposits are not, strictly speaking, of an alluvial character, but owe their origin to the decomposition *in situ* of the underlying rocks. The sands unite in giving what is practically a uniform section, which consists of from 2 to 3 feet of peaty soil, succeeded by a very variable thickness of white, gritty sand, carrying varying proportions of mica, tourmaline, and occasionally tin.

One of the most noticeable features in the structural geology of Greenbushes is the ferruginous conglomerate and gravel, the position of which has been accurately delineated by the Geological Survey of 1902. In its mode of occurrence the conglomerate presents one important feature, viz., that it does not form a horizontal table-land, but occurs at different elevations, and seems to have adapted

itself to the original contour of the ground upon which it originated. The conglomerate covered a much larger area than it at present occupies, and denudation has gone on to a large extent since it formed part of one continuous formation. The thickness of the conglomerate is nowhere very great, operations having shown that it rarely, if ever, exceeds 20 feet. In some portions of the field this conglomerate carries a certain quantity of tin. The ore, however, is not evenly distributed throughout, but seems to be concentrated in certain comparatively isolated patches. The tin from this conglomerate cannot be extracted by the ordinary process of washing without milling. Like alluvial deposits, these residuary gravels and conglomerates are evanescent, and can be exhausted.

Both the modern alluviums and the residuary sands, gravels, and conglomerates have yielded by far the greater portion of the tin turned out from Greenbushes. It by no means follows that the richness of these is proof of exceptionally rich lodes or veins beneath; for, owing to the extreme difficulty with which certain minerals are acted upon by atmospheric agencies, they often remain to gradually accumulate in much greater quantity than existed in the parent rock. It is to this natural process of concentration that the richness of the superficial accumulations of Greenbushes is due.

Tin-bearing Granite.—The tin-bearing granite consists of a granite passing in places into a foliated and highly-micaceous granite, with little or no felspar. This granite (greisen) contains tin, tourmaline, zircon, garnet, etc., as accessory constituents. In some parts of the field the tourmaline occurs in such quantity in the gneiss as to give a distinctive character to the rock, and would be better described as a tourmaline gneiss. This granite has been reticulated by a number of tin-bearing veins, forming a stock-work, and many have already been worked in the zone of surface decomposition as alluvial deposits. This area is not, however, conterminous with the legal boundaries of the field; the continuation of the tin-bearing belt should be looked for in both a north and south direction. The presence of the ubiquitous conglomerate, however, would render prospecting on the north most difficult. The best localities to search for further deposits would be along lines of greatest erosion, and that is in the vicinity of the present watercourses.

Whatever doubt there may have been as to the occurrence of ore deposits, other than superficial accumulations, has been definitely set at rest. The ore bodies are not lodes within the strict meaning of the term, but are merely a network of irregular tin-bearing veins, distributed over a fairly well-defined area. Such deposits, which owe their origin to deep-seated sources, are as likely to be as permanent as anything in the nature of such ever can be. It, however, by no means follows from this that any individual vein can be followed laterally or vertically for any great distance, but each vein will give place to another, and so on.

Owing to the extremely low assay values of many consignments of what seemed to be perfectly clean tin ore which have been shipped from

the district, attention has been naturally directed to the mineralogical characteristics of the ore. It was found that associated with the tin was a mineral of about the same specific gravity as cassiterite, rendering it almost impossible to separate the two mechanically. These investigations confirmed those made by Mr. G. A. Goyder, the Government Analyst of South Australia, in 1893.

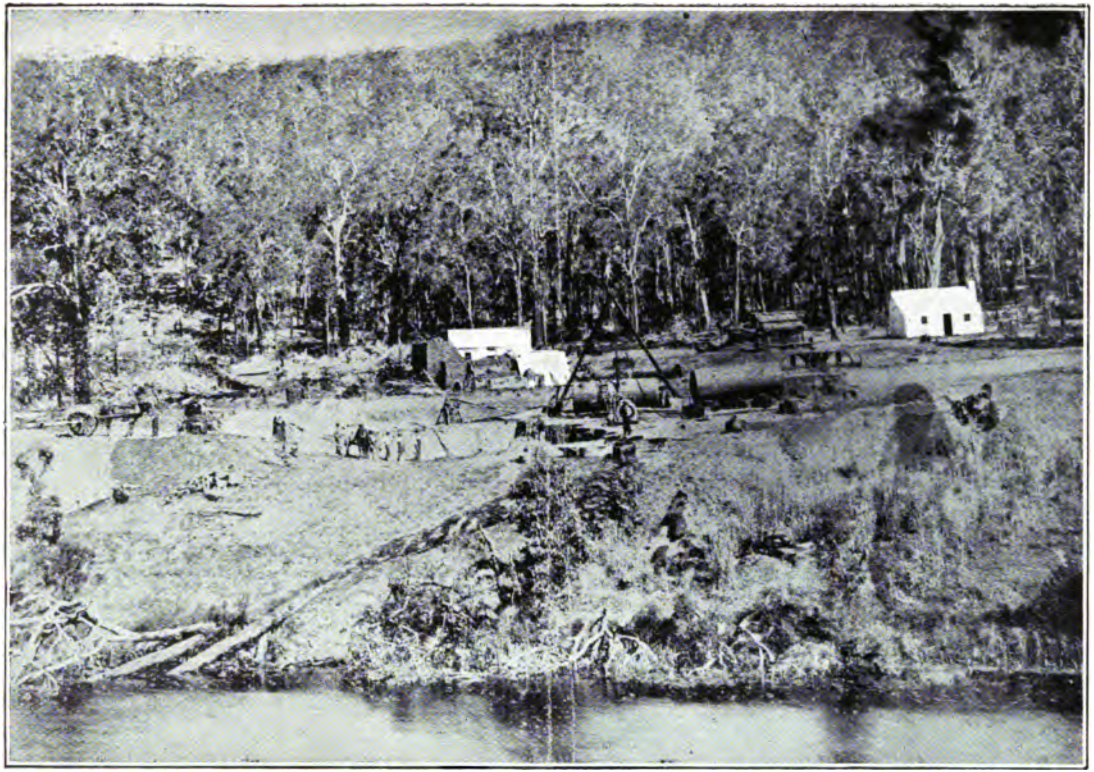
No wolfram or scheelite has been detected in the ore: the mineral once thought to be the latter having proved in every case to be stibio-tantalite. These minerals (a tantalite of antimony) and tantalite are of the greatest interest to the miners and smelters, since it is impossible to separate them from the tinstone by dressing, their specific gravities being practically identical. They have therefore to be smelted with the tin ore, and by contaminating the smelted tin with antimony, etc., seriously affect the purity and value of it. Owing principally to the presence of these two minerals, the dressed ore from the alluvial claims has been found to be very variable in richness, ranging from a trace only of tin up to 72 per cent.

A complete analysis of marketable ore assaying low in tin was made in the Departmental Laboratory, with the following result:—

Loss on ignition	·22
Tin Dioxide, SnO_2	53·14
Titanic Oxide, TiO_2	·67
Silica, SiO_2	1·61
Ferric Oxide Fe_2O_3	4·11
Alumina, Al_2O_3	·42
Manganese Protoxide, MnO	1·61
Lime, CaO	·69
Magnesia, MgO	·39
Antimony Trioxide, Sb_2O_3	15·13
Bismuth Trioxide, Bi_2O_3	Trace
Tantalic Oxide, Ta_2O_5	19.85
Niobic Oxide, Nb_2O_5	3·56
	101·40
Metallic Tin	41·80

Owing to the fact that Antimony Oxide tends to form an extremely impure tin alloy, a considerable loss of tin might result in refining. Doubtless this drawback can be overcome when the properties of the mineral (stibio-tantalite) have been properly investigated. The occurrence of this mineral may be held to explain why some of the returns to the vendors of tin ore have fluctuated so considerably.

Since the year 1891 mining has been carried out in somewhat desultory fashion, and, considering all things, a fair quantity of tin has been raised, as disclosed by the records kept in H.M. Customs House. These figures until quite recently were the only data available for



GREENBUSHES TIN FIELDS WATER SUPPLY.

arriving at the yield of the Greenbushes Tinfield, which is shown in the following table :—

EXPORT OF TIN ORE FROM THE GREENBUSHES TINFIELD.

Year.	Ore Exported.			Estimated Value.		
	Tons.	Cwts.	Qrs.	£	s.	d.
1891 -	204	0	0	10,300	0	0
1892 -	265	9	3	13,843	0	0
1893 -	171	10	0	7,664	0	0
1894 -	371	5	0	14,325	0	0
1895 -	277	3	0	9,703	0	0
1896 -	137	5	0	4,338	0	0
1897 -	95	11	0	3,275	0	0
1898 -	68	2	3	2,760	0	0
1899 -	278	8	1	21,138	0	0
Total -	1,868	14	3	87,346	0	0

Since the year 1900 steady progress has been made, the amount of tin produced during 1902 being 403 tons as against 321 tons in 1901, an increase of 25 per cent.

EXPORT OF TIN ORE FROM PILBARRA.

Year.	Ore Exported.			Estimated Value.		
	Tons.	Cwts.	Qrs.	£	s.	d.
1893 -	56	9	0	3,470	0	0
1894 -	19	0	0	949	0	0
1895 } 1898 }	0	0	0	0	0	0
1899 -	29	11	0	2,025	0	0
Total -	105	0	0	6,444	0	0

TIN DEPOSITS OF THE NORTHERN TERRITORY OF SOUTH AUSTRALIA.

The northern territory of South Australia contains 523,620 square miles, or 335,116,000 acres, and has been proved to be rich in minerals.

The Rev. J. E. Tennison Wood, in October 1886, furnished an exhaustive report to the South Australian Government describing its physical features, geology, and minerals. In this report he expressed the opinion that tin will eventually be one of the great sources of the mineral wealth of this region. No quantity of alluvial tin has been found, but lodes carrying tin are numerous; he goes on to assert that

the Northern Territory may be emphatically pronounced to be a tin-country. The extreme aridity of this vast tract of country renders it both expensive and difficult to prospect and open out. What the result of the construction of a trans-continental railway from Western Australia to the Port of Adelaide (now under consideration by the Federal Government) through this great central desert would be is still more or less a matter for conjecture, but that it would serve to open up some rich mineral areas is the opinion of all who have explored the interior of this little-known portion of Australia.

There is very little data available concerning tin-mining in the northern territory. Mount Wells appears to be the most important tin-mining centre at present. The Mount Wells Tin Mine, situated between Yam Creek and the McKinley river, bears geologically a resemblance to the tin mines of Cornwall. At the 230 feet level the lode is over 4 feet wide, tin dressing and crushing machinery being erected. The South Australian Government Geologist in 1904 reported that this lode is composed of brecciated quartz cemented by oxide of iron, carrying a small percentage of cassiterite about 50 feet wide, and seemed likely to continue in depth. The McKinley and Mount Wells Tin Mining Association held in 1898–90 five blocks containing about 3,200 acres. The tin occurred in fine crystals in quartz, slightly stained with oxide of iron. Some picked ore sent to England produced over 50 per cent. of tin. The Government Geologist visited this field in 1894, and in his report stated that it had been deserted by the white men.

Some years ago the Mount Shoobridge Tin Mine worked two small parallel lodes. The main lode varied from 2 feet to 8 feet wide, and was sunk on to a depth of 150 feet; some rich patches of ore were found, the cassiterite occurring in quartz, the country rock being composed of slates and schists.

In 1890 the Company completed the erection of crushing and concentrating machinery, and crushed about fifty tons of black tin assaying 65 to 68 per cent. of metallic tin.

Tin mining in the Northern Territory seems to have been more flourishing about ten or fifteen years ago, the gold discoveries in Western Australia and the gold discoveries near Arltunga (N.T.) having led the miners to abandon tin-mining. The Northern Territory at present offers few inducements for the white man to settle in it. It is inhabited principally by Chinamen, Japanese and Malays. With better transport facilities and the advent of the Trans-Australian railway it may yet become a certain factor in the tin production of the world. The value of the tin exported in 1902 was £5,985, and that in 1903 £10,772, so that the industry cannot be regarded as being actually at a standstill.

Tin Deposits of New Zealand and Victoria.

Tin has been mined on Stewart's Island in the South of New Zealand, but has never proved a commercial success, and at present the

output is only nominal. The tin raised being won from shallow alluvial workings in the small valleys near the base of the mountains, which are mainly granite, no lodes or stockworks of any value have been discovered, and the whole deposits may be regarded as commercially unimportant.

Tin deposits of Victoria are the least important of any of the Australian Colonies. Stream tin has been found in the Beechworth district, and in 1880, 103 tons were obtained, but at the present day little or no unworked alluvial tin drift exists.

Various attempts have been made to work the numerous small tin lodes known to exist in the Mitta Mitta valley, but none have been attended with success up to date. In 1897 the author inspected a number of small tin lodes in this district. The country rock was a coarse-grained porphyritic granite, with the felspar crystals large and well developed. The cassiterite occurred in irregular masses through some of the small lodes which traversed the granite country, but no attempt was made to work them on a large scale. The general average of the ore was too poor to pay; when opened out the lodes were proved to be most uncertain in depth.

At Mount Wells tin has been found in veins and disseminated in granite, forming a true stockwork, and gave the promise at one time of being a paying proposition. The best year for the production of tin was 1891, the output being 1,778 tons valued at £5,092, but it has sunk practically to nothing at the present time.

* In the Beechworth district payable alluvial tin ore has been found, several samples assaying up to 12 per cent. A number of miners are engaged in washing the alluvial for stream tin in all the gullies and little creeks falling from both sides of the range.

* "Mining Journal," Oct. 20, 1906.

CHAPTER XI.

THE TIN DEPOSITS OF BOLIVIA.

*THE tin-producing districts of Bolivia are situated on the Eastern Cordillera of the Andes, between latitude 21° S. and latitude 16° S., extending north and south over a distance of 300 miles, appearing in distinct groups. They are all to the eastward of the great Bolivian plateau, in which are the lakes of Titicaca and Poopo. No tin mines are known to exist in the Western or Coast Cordillera.

GEOLOGICAL.

The Andes in this district are of the Silurian series, and include the rocks of both the Upper and Lower Silurian formation, abutting to the westward on the old lake bed. The formation is of great thickness in the valley of the Arque, at the foot of the mountain of Berenguela, a height of 6,000 feet above sea level. Nearly the whole stratification can be seen plainly up to a height of 14,000 feet, and it is the same up to the summit of Tres Cruces, at the height of 20,000 feet.†

This range has been disturbed by eruptions of porphyritic rock, which shows plainly in isolated groups of hills, such as Oruro, Sicasica (Garce Mendoza), and others, which formed islands in the great lake; these porphyritic rocks are the chief feature in this range. Prior to these eruptions of porphyry has been the intrusion of the granite, which is abundant in the eastern ranges, but is more seldom seen in the main range.

These eastern ranges consist of slate or layer upon layer of greywacke, shales, and thick beds of sandstone; they are generally auriferous. Further to the south the eruptive rock is trachyte, and near to Chile and the Argentine Republic the rocks are gneissic, or schists broken up by granitic intrusions.

On the western side of the lake-bed the formation is distinct with rocks of the oolitic series, with a belt of Permian formation, in which are situated the copper veins of Coroccoro, San Bartolo, etc.

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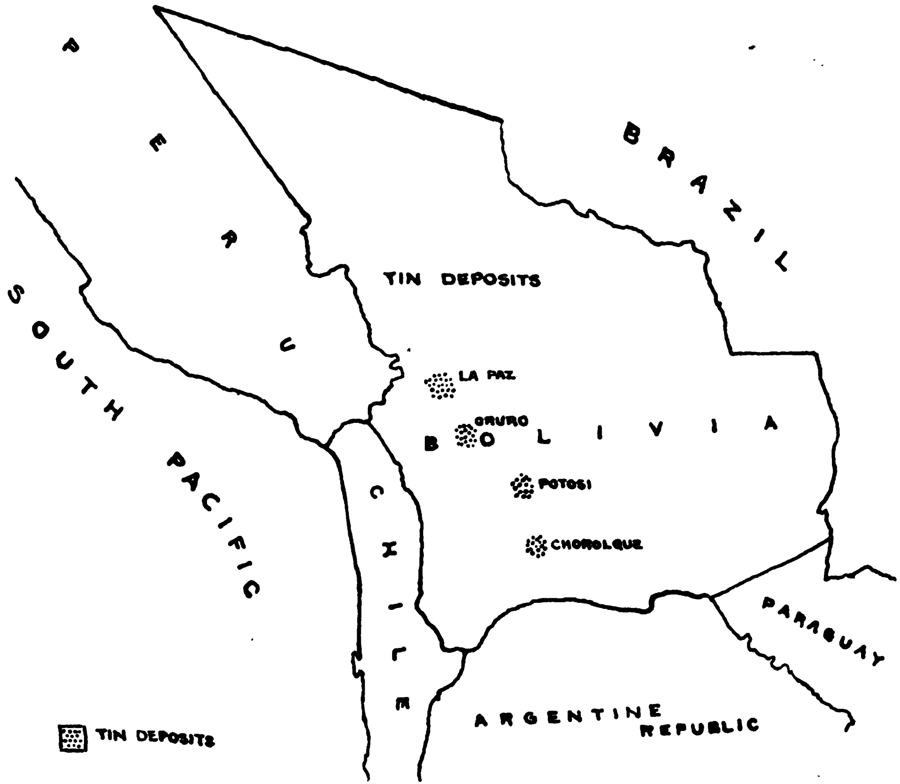
* Chas. S. Pasley, "Inst. of Min. and Met.," 1898.

† The cleavage in general is from north to south with the dip to the eastward, most of the lodes cutting the stratification at right angles. This appears to be the same in the silver mines.



MAP OF BOLIVIA—SHOWING POSITION OF TIN DEPOSITS.

There are scarcely any signs of volcanic action east of the old lakebed, except at La Paz, and earthquakes are unknown.

Nearly all the tin lodes occur in the porphyry, or altered andesite, but in a few places the lodes run through slate and trachyte. The veins in the porphyry were generally the richest and of better quality, the others being mixed with antimony, iron and copper pyrites, zincblende, and sometimes with bismuth and wolfram. The tin usually has traces of silver, and the lodes frequently have a capping of iron.

Mines.

The tin-producing districts may be divided into four; Oruro in the centre, La Paz in the north, Chorolque in the south, and Potosi further to the eastward.

Oruro is by far the most important of these districts, the amount of tin sent from Oruro being above two-thirds of the total production of Bolivia. The following is a brief description of the principal mines of the country, commencing with the hill of Huanuni—the most important mines of the Oruro district.

Huanuni Hill.—The mountain of Huanuni has an imposing appearance, rising over 2,500 feet above the river which flows at its base, and is about 15,500 feet above sea level.

The principal lodes run nearly east and west, dipping to the south, cutting the strata at right angles in one part of the hill, and at an angle on the opposite side. The stratification is very irregular, and there are a number of faults. Four of the principal lodes run nearly parallel, and have a dip of about 50° to the south. These lodes run across to another hill of slate, their character changing with the different rock, being mixed with arsenical pyrites. There are three or four other cross lodes, but these are not nearly so rich—these cross lodes seem to be of later formation.

There are several proprietors on this hill, the chief owner being the Huanuni Company and a Bolivian firm. There are also about half a dozen others.

The lode worked by the Huanuni Company, named the Catarecagua, varied in width from 2 to 8 feet. The ore is fairly continuous throughout, but has rich shoots. The Spaniards, who were former owners, worked down on one shoot to a depth of 1,000 feet vertical. This part is now cut by a tunnel and worked by more modern methods. The old working is used for ventilation; formerly the ore was partly sorted at the bottom of the mine and then carried out on men's backs—a man could only make two journeys in a day, carrying 75 lb. at a time. There are signs of galleries in several places, but these were all blocked up with the dirt carried up from below.

The tinstone is generally richer on the foot wall, but the tin is fairly good throughout. Both the rock and the vein matter are very hard. The sorted ore from the lode as a rule contained about 50 per cent.

of oxide, and the poorer stuff about 20 per cent. The ore picked over by women, who generally throw away any stuff containing less than 10 per cent., is all put on one side to be worked at some future time as there is sufficient ore of the richer quality to keep the floors going. This mine produced about 100 tons of concentrates per month.

This company has a 10-stamp mill and several jigs and round buddles, the floors being worked on a modified Cornish system which was very successful. The tailings from the floors contained about 5 per cent. of oxide. These were all saved to be worked over again.

The ores that were being sorted were extremely rich; some of the ore gave 65 per cent. of tin without concentration, and the dumps ran about 15 per cent. of oxide. They had struck a very rich pocket in soft ground, and had taken out 2,000 tons of concentrates.

Their work was all done on the old Spanish system—all the ore and dirt being carried on men's backs, and the floors were managed in the same fashion. The ore was washed by women in a narrow trough about 12 to 18 inches wide. The bottoms of the troughs are made of peat, with a curve so as to gradually lessen the force of the stream of water. The ore is moved up against the water by a thin piece of wood a little shorter than the width of the trough until the dirt has been carried off.

This process is exceedingly wasteful, nearly all the slime tin being lost. The ore was crushed by a Chile mill, worked by mules.

Several of the other mines appeared to be important, but were badly worked. The total production of the mines in this hill amounted to about 250 tons of concentrates of 65 per cent. metallic tin per month. Some of the lodes in this hill had a large quantity of pyrites, but these were not worked.

Close to Huanuni at the base of the hill are several veneros or deposits of stream-tin; some of these were worked on a small scale on tribute; the quality was very good, but the quantity produced very small.*

MOROCOCALA.—Ten miles north of Huanuni are the mines of Morococala, Vilacollo, and Negro Pabellon, on hills of the same names. At Morococala are three mines with different owners. The principal one is worked by a shaft sunk on the lode, which is 12 to 15 feet wide in places, and carries very rich and pure oxides.

VILACOLLO, a short distance from Morococala, was abandoned, and most of the workings had caved in owing to the softness of the ground and want of timbering. Large quantities of ore had been taken out of this mine in former years. The quality of the ore was

* The extent of the "veneros" was very large. These had been prospected by the natives in various places, and the best patches worked. There was plenty of water, but very little fall could be obtained. Some of the patches had too much iron, but in many places the stream tin was in large rounded pieces weighing a couple of pounds, and nearly pure oxide. No system was observed in working the stream tin—each man working where he pleased on tribute, and generally stealing about half the tin that he obtained.

bad, the percentage of iron being very large. A caretaker, who had worked in the mine, said that it was not a lode, but only a shoot. There was no trace of walls ; the surrounding rock was sandstone of a deep red colour, impregnated with iron. All the dirt taken out of the mine contained tin-stone mixed with iron oxide and pyrites. A shaft of 250 feet had been sunk at the bottom ; there were no traces of tin, the metal containing a little silver with arsenical pyrites. The floors were three miles from the mine, there being no available water nearer. They were of the native type with a large Chile mill for crushing.

Negro Pabellon, a mine owned by a German firm, and worked on tribute by a Chilian miner, was of quite a different type to the others mentioned, the lode running north and south and vertical, and in the same direction as the cleavage. The dip of the strata was about 45° E. The country rock was slate, and the lode contained the same rock and tin-stone mixed with iron pyrites. The tin was very rich and easily worked, the ore averaging 20 per cent. from wall to wall. The lode seemed very regular, about 3 feet wide, crossed by several small veins; rich pockets were encountered wherever the lodes crossed. The mine had not been worked to a greater depth than 100 feet. The tinstone was soft and easily washed and crushed ; the concentrates gave a very high percentage of tin, up to 70 per cent.

The floors were of very small dimensions, as the water was very scarce, hand jigs, and various hand troughs for hand washing were used. The crushing was done by a Quimbalete, or rocking stone. A short distance from the mine were old floors with an iron overshot wheel for driving a 4-stamp battery, but the water was not sufficient to turn the wheel round.

The mines of Morococala and Negro Pabellon are about 15,000 feet above sea level. In each of the watercourses between Huanuni and Negro Pabellon were found one or two people washing stream-tin. The principal venero was at Japo. This stream tin was in patches and of good quality, but there was very little water in the streams. The natives who work in this way are quite contented if they collect and sell 1 cwt. per week per man, but very often these stream-tin washers will collect about 10 to 12 cwt.

Colquiri.—Fifty miles to the north-east of Oruro are the mines of Colquiri. They are situated in the province of Inquisivi, which officially belongs to La Paz, but it is over 100 miles from that town. The principal lode, which is of great width, was worked by the Spaniards for silver chlorides. The deepest working that was discovered by the author was 175 feet from the surface ; this reached the water level. This lode can be traced for 3 miles on the surface, having immense "desmontes," *i.e.* dumps, all the way along.

There is a tunnel about 1,000 feet long cutting the lode just above water level, and in another part an adit nearly as long. The vein matter is 80 feet wide in the tunnel. The walls are well marked and vertical. The lode runs N. 80° E. and S. 80° W. The tin on the

south wall had been worked on either side for 150 feet, and had been stoped out up to where it was covered by the silver chlorides. The tin had apparently been in pockets, as the width of the workings varied from 2 feet to 10 feet. By the books the people who had worked it had sent away over 500 tons of concentrates. The author found specimens that were mixed with pyrites that gave 75 per cent. of oxide. Beyond this streak of tin the vein matter consisted of arsenical pyrites, magnetic iron, copper pyrites, heavy spar and iron oxide, with narrow veins of galena about half an inch wide, dipping across the other vein matter to the north. These galenas contained about 100 ounces of silver to the ton. Beyond these, next to the northern wall of the lode, was a wide streak of grey clay mixed with iron pyrites in large lumps with tin and fluorspar disseminated throughout the clay. Water was filtering through this streak, which averaged 8 feet wide. It was expensive to work and had been abandoned, as the stone archwork was too expensive to build. The tin stuff averaged 4 per cent. A shaft had been sunk in the middle of the lode for 75 feet. This was full of water, which could not be handled without machinery. The water that ran out of the tunnel was used for washing on the floors. An analysis of this gave 1½ per cent. sulphuric acid, and 1 per cent. of copper. The ores were first concentrated to about 40 per cent., and then roasted in a reverberatory furnace and re-concentrated.

Twenty miles north of Colquiri is the Tres Cruces, a large group of mountains 20,000 feet high.*

The only tin lode worked was Sayaquiri. The lode was about 25 feet wide; the tinstone was mixed with iron pyrites, and also contained wolfram; wherever any sinking on the lode had been done the tinstone got worse in quality. This lode ran E. and W., and was nearly vertical; in other lodes the tin was remarkably pure, in brown coloured crystals, the concentrates giving 70 per cent. of tin, but these veins were at a great height, far from water, and snow-covered half the year.

Here was found a large block of nearly pure oxide, about 2 feet thick, among the detritus at 18,000 feet. The lodes contained tin mixed with antimonial silver, running at nearly right angles to veins of gold-bearing quartz, but one could never see the actual place of crossing or where they had been cut off; also this part was too far from the railway, 85 miles by road, making the freights too high.

The mines of Oruro are well known as silver mines; most of the lodes have tin on the surface, which sometimes penetrates to a considerable depth, mixed with the silver ores. All the work is carried on for silver, no account being taken of the tin until the silver has been extracted by amalgamation (with the exception of a few contractors who work the tin stuff found on the dumps and close to the surface).

There is no water at Oruro available for floor; the ores are carted

* All the tin lodes in these hills were at the southern end; in the eastern side all the veins were silver and galena, and to the north auriferous quartz.

to the amalgamation establishments about 15 miles off. There are two of these, "Machacamarea" and "Obrajes."

The tailings of the silver ores are washed for tin; about 50 tons of concentrates are obtained monthly. The tin is not of good quality and is very variable in quantity. It is nearly all worked on tribute. Frue vanners were used for concentrating.

At Oruro there are several large deposits of slags left there by Spaniards who smelted the Oruro ores for silver; these slags contained 30 per cent. of tin and 20 per cent. of lead and some silver. A quantity was shipped to the coast to be re-smelted, but did not pay.

At the mines of Challa-Apacheta, 12 miles south of Huanuni, which were worked for some time by a Cornishman, there is another curious instance of a very wide lode, which is about 120 feet wide with the tin in patches, the vein matter consisting of clay and iron oxide, the tin being principally slimes. All the tinstone was mixed with arsenical pyrites and iron oxide; the vein matter was very soft and could be worked with picks. The tin averaged about 2 to 3 per cent., but was easily worked. The slimes were of very good quality. Whenever a good-sized hole had been made a cave-in would take place, and the dirt was wheeled out to the floors until no more dirt would fall. There were workings on one side reaching a depth of about 100 feet. The ore here was very dirty and of bad quality; the lode appeared to be changing into pyrites at this depth.

The floors were worked by the Cornish system with square buddles and kieves. There was a scarcity of water in the dry season.

THE MINES OF ABICAYA.—About three miles to the south east of this mine is the hill of Challa Grande, with the mines of Abicaya, Totoral, and Chuncho.

The veins in the two first named run east and west nearly parallel, varying in their dip from 60° to 40° to the north.

The lodes are all in very hard porphyry, the tinstone being very pure on the foot walls, but sometimes on the hanging walls, with shoots of ore occasionally from side to side, the veins varying from 1 foot to 5 and 6 feet wide; all the vein matter was very hard, and had a lot of quartz with it. The tinstone was sometimes in fair-sized black crystals, but generally in compact masses. The tinstone taken from the walls averaged 40 per cent., and the rest of the vein 20 per cent.; the lodes were all well formed and very regular. These mines are situated on a spur of the hill, one on each side, Abicaya being 400 feet lower than Totoral. Chuncho is still higher and near the centre of the hill. The lodes here run north-east and south-west, and are vertical crossing the lodes of Abicaya and Totoral. The tinstone in these lodes was softer, but more mixed with pyrites and iron oxide.

The floors of Abicaya consisted of a Gruson ball mill, a three-compartment jigger, and a Frue vanner, which seemed to suit the class of metal fairly well. These were driven by a turbine; this could only be run half time during the dry season. The floors of Totoral consisted of Cornish jigs and square buddles, the ore being crushed with rocking stones shod with iron.

Further in the interior, about 30 miles east of Abicaya, are the mines of Uncia and Llallagua, both on the hill of Uncia. The road of Llallagua runs east and west and nearly vertical. The mine was badly worked; the tinstone was rich and of good quality, occasionally mixed with pyrites, and often occurring in masses of large crystals. The lode contained a large amount of oxide of iron; the ground was soft and easily worked; the floors consisted of square buddles, with a rocking stone for a crusher.

At Uncia the mines were worked on tribute; the lodes were wide and well formed; one of them, a cross lode, had an adit about 300 feet in length; the tin was mixed with silver and copper pyrites.

Further in the interior, about 70 miles east of Oruro, are the mines of Berenguela in the mountain of the same name. These mines are the furthest east of the Oruro district. The lodes, of which there are several, are wide, apparently running north-east and south-west with a dip to the north. The mouths of only two of the mines were visited by the author, who had to judge of the others by the lines of "desmontes." The tin stuff is nearly all in slimes, and ran about 6 to 7 per cent. on an average, and of very good quality. The hill is exceedingly steep; the mines are nearly 13,000 feet, whilst the valley at the base of the mountain is 7,000 feet above sea level. On one side of the hill there were masses of purple porphyry, and lower down several spurs of the mountains appeared to be of red sandstone. Trees grew wherever they could get sufficient hold, and water, both for washing and power, was more than enough. These mines belong to the department of Cochabamba, their outlet being by Oruro.

La Paz.—The mines in the La Paz district are not of great importance; one of them, Chacaltaya, had a wide but very uncertain lode, and had floors consisting of a Huntingdon mill, jigs, Frue vanners, etc., driven by a Pelton wheel; but the tin production was insignificant. The most important mine was that of Milluni. The work was left almost entirely to tributors, who had been allowed to ruin the mine. There were several small workings on the hill of Huayna Potosi; these were at the snow level, and were not visited by the author. The whole tin production from the La Paz district is slightly over 300 tons of concentrates a year.

*Chorolque mountain is situated in the south of Bolivia (about 21° S. and 66° W.), on the boundary line of the provinces of North and South Chichas, in the department of Potosi. Its highest point is nearly 20,000 feet above sea-level. The mine is worked at an altitude of nearly 18,000 feet, and Santa Barbara, the site of the concentration works, is about 16,000 feet above sea-level. A good mule accustomed to the high table-land of Bolivia can get right up to the mine, along a rough zig-zag path, with perhaps even less fatigue than a llama. The peak is generally more or less snow-capped, except in the month of November, when for a short time a little ice is visible. The south of Bolivia is noted for prevalence of high winds, and the

* Malcolm Roberts, "Inst. of Min. and Met.," 1901.

heights of Chorolque are never free from wind, which at times is so strong as to make the working of the wire ropeway impossible, as the cars are blown off. During the rainy season there are great electrical disturbances. The distance from the nearest railway station—Uyuni, of the Antofagasta-Oruro Railway—is 30 leagues. Thence to Quechisla, 4 leagues from Santa Barbara, carts can travel ; but between the latter two places there is only a mule track, on which the upward journey is very hard work.

"There appears to be no other valuable mineral, at least to any notable extent, in the mine at present working, than cassiterite.

"*The mine* belongs to Aramayo, Francke & Co., and through the courtesy of their representatives I obtained access to it. The workings are at a great altitude, most probably because the lode lower down does not contain tin. The mode of working is by means of adit levels driven on the lode, connected by winzes or ore-passes. The lode runs east and west, with a slight but variable dip to south, crossing the precipitous southern face of the mountain ; its outcrop has suffered great denudation. It is generally about 3 feet wide, and often half of this is rich tin-ore ; but at times it pinches into streaks, which frequently carry pretty crystals of cassiterite on one side and quartz crystals on the other. It has numerous little branches or leaders, which may be well mineralised for a short distance and then die out. The walls are not well defined. The richest point seen was the deepest in the mine, at the bottom of a winze over 300 feet from the outcrop. The tin-stuff sent from the mine to the concentration works contains, as far as I could ascertain, never less than 25 per cent. of metallic tin. No heed is paid to the numerous subsidiary shoots from the main ore-body ; they are broken and used merely for filling the depleted stopes. One cannot help suspecting that these off-shoots must to a certain extent be impregnated with mineral, and that the filling must contain a fair average percentage of tin. I did not see any systematically prepared stoping ground. Probably through the richness and constancy of the main lode no detriment arises from lack of development work kept well ahead of stoping.

"An interesting project in hand is a cross-cut to the north to open up other lodes which are believed to exist.

"The cold in the mine is intense, and this prevents the men from idling. Though an end may be deficient in ventilation, which in other mines would cause an unpleasantly high temperature, here the gallery is glazed with ice. The ore on coming out of the mine appears very dry, but exposure to the sun on the way to the concentration works renders it a wet mass through the thawing of the ice.

"*Works.*—The ore is taken down to the concentration works on a wire ropeway with two intermediate stations. The works themselves are small, and embrace ball mills and jiggers. A windmill is about to be used for power. There is no classification, and apparently no treatment of fine stuff. Not long ago the grinding was done by rolls, followed by good classification before jigging. Why a ball mill without classification should have taken the place of the former installation is

not easily understood. Grinding dry in a ball mill must produce a fair proportion of fines, and one would think that with such rich ore (25 per cent.) fine grinding would serve no purpose, and that rolls would be preferable.

"The dry-ground stuff is dropped into the running water of the jigger, and much slime must float away. I have reason to believe that the waste dump contains 3 to 4 per cent. of tin, and therefore is about as rich as the Dolcoath lode. It will probably be re-worked in the future; but the slimes from the jiggers can never be recovered. The ore is dressed up to about 60 per cent. metallic tin, and in that state is exported as 'barilla' to Europe. The maximum production is 5 tons daily.

"Only within recent years has any practical attention been paid to the alluvial deposits. Work is now carried on for miles by private persons on a small scale in all the quebradas or gullies leading from the peak. The richest and at the same time almost unique occurrence is called the 'Salli.' This is formed of immense heaps of debris at the immediate foot of the watercourses of the steep southern face of the peak. These heaps had their origin in the outcrop of the lode, and they convey a good idea of the tremendous disintegrating agencies at work here, and of the enormous denudation which the lode must have suffered. Although these heaps are at no great distance horizontally from the lode, they do not form part of the possessions of the mine. They were being worked by private individuals in the following manner :—The tin-stone is picked out of the heaps by hand, and taken a short distance on the backs of llamas to where there is water. Part is hand-broken and selected, and gives 60 per cent. tin; the remainder, after breaking, is ground by hand under big stones (*trapiches*), then washed in a jigger to 50 or 60 per cent. and exported. The gullies in the rainy season are torrents at times, so that great lumps, weighing some pounds, of almost pure cassiterite are carried from these heaps, and are met with miles away. The loose bed-stuff of these gullies, not counting boulders, for a distance of 4 miles contains up to 3 per cent. tin, and the hillsides ½ per cent. Work is done in a very primitive fashion, and is confined to the beds. Holes being made, the larger tin-stones are picked out at once by hand, and the smaller material is put into a sort of sluice or box about 6 ft. long. Probably even by this crude method of washing not much tin is lost, because, owing to the steepness of the gullies, all fine tin must be swept down to the rivers. The dirt on the hillsides, fairly extensive in some places, has not been worked as yet, and it will probably remain untouched for a long time, because the torrent beds form natural concentrators, and receive fresh supplies during every rainy season. The difficulties of working on a large scale are want of capital and of men, and particularly the natural difficulties presented by the paucity of water and the cold climate. During seven months of the year little work can be done, as the water is frozen, and only for a few hours daily does it thaw sufficiently to give a stream and permit working. The summer months, when it rains, have to be relied on for output.

These deposits at present do not produce more than 25 tons of 'barilla' per week, so that the total output of the Chorolque district is about 175 tons of 'barilla,' or say 105 tons of bar tin monthly. At La Paz I visited the recently discovered Kimsi Cruz tin-mining region, situated at an elevation of from 15,000 ft. to 17,500 ft. above sea level. Tin occurs here under totally different conditions from those in Australia. The country rock is altered slate, with occasional bands or seams of porphyry, conforming to the strata. The tin ore is a mixture of cassiterite and iron. Copper pyrites occurs in bedded deposits at times, forming a contact with the porphyry, but mostly only forming a separate bed in the slate. A most peculiar feature is noticeable in connexion with the value of the ore. That is, that the highest mines—those, say, above 16,000 ft.—are richest, the tin contents, in beds 1 and 1½ metre in thickness, running up to an average of 10 per cent. metal, whereas beds or lodes in lower country are worthless. One mine, the Monte Blanco, was recently sold to a Chilian syndicate for £170,000 cash, a tall price for an undeveloped mine, and, in consequence, owners are asking about ten times the value of any holding showing any ore. It is probably a good field, and will be developed in time, but climatic conditions are awful at that altitude. Only Indians born in the locality can work, all imported men being unable to do more than just move about, on account of the rarefied air. Although the district is well in the tropics snowstorms are of frequent occurrence, both in summer and winter. The native so-called miners are now receiving 5 to 6 bolivianos a day (about 9s.), and the men are very scarce at that. The mine owners, therefore, are endeavouring to secure Government sanction to import Japanese miners, as being hardy."*

Potosi.—There are not any mines in the hill of Potosi that are especially worked for tin. As at Oruro, the silver lodes are mixed with tin near the surface. Most of the tin stuff is taken from the dumps of the old workings by tributors, who sell it to a smelter; these smelting works use water-jacket furnaces; the bar is of very bad quality, as the metal is very much mixed with antimony and other metals.

The fuel used is charcoal and llama dung. The smelting pays well as the railway is 150 miles off; a good quantity of bar tin is sent from here.

Ten leagues from Potosi are the mines of Porco. These mines are not worked; they were abandoned as the ore was too poor to work. The tinstone ran about 7 per cent. on an average; there were a number of lodes, and the floors were worked by water-power.

To the north of Potosi are the Maraguas mines and the veneros of Ocuri. The Maraguas mines were worked by fits and starts; they were not paying. The lodes, of which there were a great number, were narrow and close together. The tinstone was rich. No proper

* "Mining Journal," Sept. 29, 1906. An Australian's account of Bolivia's mining industry.

work had been done to develop these lodes, as the work was done by tributors.

The veneros of Ocuri were worked by two Cornishmen, and had given excellent results. The tin was plentiful and of very good quality. There was plenty of water in the river, and the work was carried on systematically. These veneros were a long distance from the railroad—over 90 miles.

Many lodes exist in all of these districts which cannot be worked, as they are claimed by people who never intend to work them. Anyone can hold a mine on payment of a small fee and a yearly fee of five Bolivian dollars—less than 10*s.*—a year per hectare. These people do not pay the yearly fee after the first year; but if anyone else claims the mine the result is a lawsuit, which may last for years.

The progress made of late years in the tin-mining industry is due chiefly to the completion of the Antofagasta and Bolivia Railway which was opened to Oruro in 1892. This has lessened the freights and thereby enabled many people to start work; formerly all the traffic was carried on by mules, donkeys, and llamas from Oruro to the port of Arica in Peru. Before the opening of the line the cost per cwt. used to be :—

By mules in 5 to 7 days - - -	about 10*s.*
By donkeys in 12 days - - -	,, 8*s.*
By llamas in 30 days - - - -	,, 5*s.*

It is now about 2*s.* 6*d.* per cwt. in three days by rail. The difference with regard to machinery is still greater, as formerly all parts had to be made for mule transport.

The smelting of the ores up to the present is not on any large scale. The ores smelted at Quechisla from the Chorolque mines would probably pay as well if sent away as concentrates, and the ores smelted in Potosi are those of very bad quality, the concentrates being so dirty that no merchant would purchase them, except at a very low figure; for this reason the smelters buy them at a very low rate, and make money by saving on freights. The railway company charge double freights for all goods sent from the coast. The cost of coal, chiefly Australian, is about £8 per ton delivered at Oruro—a prohibitive price for smelters. The object of the railway company is to secure as much freight down to the coast as possible.

Workmen are easily obtained, though they are not as plentiful as formerly. Most of the mining is done by Cholos, *i.e.* half-breeds. Indians can be obtained for outside work, building houses, making ditches, etc. They are not as highly paid as the Cholos, and are much less trouble to look after.

These districts are all at a very high altitude, and are very healthy. As a rule Europeans soon become accustomed to the rarified atmosphere, and live perfectly well at 16,000 ft. From May to August the cold is intense, the thermometer often falling below zero (Fahr.) The differences of temperature are very trying at times. The thermometer

has shown 70° in the sun, and 10° of frost in the shade, as there is hardly any radiation at these heights.

Location.	Name of mine.	No. of lodes working.	Direction.	Dip.	Rock.
Huanuni Hill -	Catarecagua -	1	E. & W.	50° S.	Porphyry.
" " -	Barreno - -	1	N.75E.	60 S.	"
" " -	San José - -	1	N.80E.	45 S.	"
" " -	Dejada - -	1	E. & W.	50 S.	"
(Penny Bros.) -	Vetilla - -	1	E. & W.	70 S.	"
" " -	" - -	1	N.70E.	—	"
" " -	Various - -	—	—	—	"
Negro Pabellon -	Negro Pabellon	3	N. & S. (2 cross lodes).	Vertical	Slate.
Morococala -	—	3	E. & W.	"	Porphyry.
Vilacollo - -	Vilacollo - -	1	—	—	Sandstone and slate.
Colquiri - -	Socabon Verde -	1	N.80E.	Vertical	Slate.
Tres Cruces -	Sayaquiri -	1	E. & W.	"	Porphyry.
Oruro - -	Various - -	—	—	—	"
Challa Apacheta	Challa Apacheta	1	N.45E.	Vertical	Slate.
Challa Grande -	Abicaya - -	4	N.80E.	50 N.	Porphyry.
" " -	Totoral - -	4	N.80E.	50 N.	"
" " -	Chuncho - -	3	N.E.	Vertical	"
Uncia - -	Uncia - -	2	N.80E.	"	"
" - -	Llallagua -	1	E & W.	"	" and slate.
Berenguela -	Various - -	—	—	—	Porphyry.
La Paz - -	Chacaltaya -	1	N.50E.	—	"
" - -	Milluni - -	—	—	—	
Chorolque - -	Santa Barbara -	1	E. & W.	Vertical	Porphyry.
Potosi - -	Various - -	—	—	—	"

The total production of tin in Bolivia, according to the yearly statement of the Minister of Finance, taken from the amount of export duty paid, represents 5,910 tons of bar tin; but in these figures the concentrates are not separated from the bar tin, so that the exact figures cannot be given.

In the year 1893 the exports amounted to 2,000 tons, so that in five years the production of tin has been trebled. These figures were received after the author had made an approximate table of the amounts produced at the various mines.

The export duty charged is :

50 cents per 100 lb. of bar tin - - 9*d*. nearly.
35 " " concentrates - 9½*d* "

The author is indebted to Señor Avelino Aramayo, the Bolivian Minister in London, for these figures.

Location.	Name of mine.	Height above sea level. Feet.	Monthly production in tons of Barilla.
Huanuni Hill	Catarecagua	14,500	100
" "	Barreno	15,000	"
" "	San José	"	"
" "	Dejada	"	"
" "	Vetilla	"	25
" "	Various	14,500	10
" "	Vetilla	"	15
Morococala	Various	15,500	30
Negro Pabellon	Negro Pabellon	15,000	30
Vilacollo	Vilacollo	14,000	—
Colquiri	Socaben Verde	"	10
Tres Cruces	Sayaquiri	15,000	10
Oruro	Various	13,000	50
Challa Apacheta	Challa Apacheta	14,000	5
Challa Grande	Abicaya	15,000	35
" "	Totoral	15,500	35
" "	Chuncho	"	—
Uncia	Uncia	14,000	10
"	Llallagua	13,000	35
Berenguela	Various	14,000	—
La Paz	Chacaltaya	15,000	25
"	Milluni	14,000	25
Chorolque	Santa Barbara	16,000	35
Potosi	Various	14,500	20

About 70 tons of bar tin is sent monthly from Chorolque and Potosi, or about 6,000 to 7,000 tons yearly.

In the figures of production other small mines contribute; these figures are difficult to obtain correctly, as the owners are given to exaggerate the output of their mines, and the total of 7,200 tons of barilla yearly of 65 per cent. of tin, equal to, say (with loss on smelting), 4,650 of tin, counting the bar tin as 1,000 tons yearly, gives a total of 5,650 tons.

Mine.	Sn.	Fe.	Gangue, &c.	Remarks.
Catarecagua, Huanuni	37·05	6·75	56·20	Average value.
Barreno	79·00	4·25	16·75	Picked ore.
Morococala	68·00	7·15	24·85	Traces of silver.
Socabon Verde, Colquiri	4·30	15·20	80·00	" "
" " "	72·00	7·50	20·50	Picked ore.
Oruro, Salinas	17·25	12·25	70·50	Traces of silver.
Totoral, Challa Grande	84·50	3·25	12·35	Picked ore.
Uncia, Llallagua	46·00	14·00	40·00	Traces of silver, some antimony.

* According to Juan B. Minchin, the mining of tin in the vicinity of Oruro, Bolivia, made considerable progress during the year 1903.

* "The Mineral Industry," 1903.

The output of tin concentrates or barilla for the year amounted to 3,721 tons, averaging from 64 to 71 per cent. metallic tin. This production was divided among five mines, the largest of which is owned by Abelli and Company, of Abicaya. The mine is opened by a shaft of 95 meters depth, which is provided with a steam hoisting engine. The ore is crushed in a stamp mill, and is then concentrated by jigs, buddles, and Wilfley tables. The Huanuni mine has reached a depth of 80 meters. The crushing machinery consists of a 10-stamp mill, and its capacity is to be doubled by the addition of ten more stamps. The Chuncho mine is a comparatively new enterprise. It is supplied with a mill of 10 stamps. At the Uncia mine the ore is crushed in part by small rolls and in part under rocking stone, and the concentration is effected with a Wilfley table, jigs, and round buddles. The company is building a wagon road 45 miles long to the nearest railroad station, and will erect a new plant near the mine. The Quinsa Crur district, in the province of Inquisivi, has received a good deal of attention recently, and important deposits apparently exist. Little development work has been done as yet owing to the scarcity of capital and defective means of transport. The mines of the district are situated in the Great Cordillera, and have an advantage over most mines of Bolivia, in that there is an ample supply of water for power purposes.

* Tin Production.

The idea is prevalent that tin ore is superficial in Bolivia; only time will prove or disprove the correctness of that idea. In many cases up to the present such is not true. Be that as it may, if there is no further notable increase for some time in the output of Bolivian tin, it will not be through want of ore in the lodes, but through scarcity of labour. With the constant installation of new workings, the extensive railway construction, &c., hands are getting more and more difficult to obtain. If capital is not forthcoming to make automatic appliances available, inside as well as on the surface of the mines, I am afraid this labour difficulty will be practically insuperable for a long time to come, taking into account the conditions—geographical, social, and political—of the country: and, therefore, the greatest efforts in the Bolivian mines are not likely to suffice to make any very appreciable impression, in the near future, on the actual high price of bar tin.

The mining laws in Bolivia are exceeding liberal and good, but their administration does leave a good deal to be desired. This is undoubtedly due in a great measure to a want of competent officials and proper archives. In the past there has generally been such a lot of ground vacant that there was room for all, without the necessity of great exactitude in mining locations; but now, when competition is becoming

* "Mining Journal," Sept. 1, 1906.

rife, the Government must be impressed with this important matter of correctly administering the law. A straightforward and good man as Prefect of Potosi, to whom all mining petitions are directed, with power to overrule opposition to such petitions in cases where the objections are ridiculous, as some of them are, would in those cases save a lot of time and trouble. Again, the Government must obtain competent engineers for locating the concessions. Even at present, as a rule, these are given or plotted by "peritos fiscales" with no knowledge whatever of surveying, and it can well be understood that in hilly districts, such as almost all the mines comprise, a concession staked with only a string or a tape is not liable to come out very exact; so that the best way at present is for every petitioner to have his claims properly laid out and surveyed beforehand, leaving nothing for the "perito fiscal" to do except quickly measure round to obtain his conformity. Such is the procedure of every mining company here which has an engineer. In time such conditions will disappear, their existence being due chiefly to the shortness of Government receipts which have not been sufficient to maintain the required number of official engineers. At present law-suits should be avoided, and many of them could be settled in the beginning, even if the opposer has some reason in presenting his objections, by employing a little tact and a trifle of money. In case a law-suit must be faced, the "via ejecution" should be chosen, and not the "via ordinaria," as the obtainment of judgments in the latter procedure might very well last a lifetime.

Bolivian Export Duties on Tin.

* The Board of Trade are in receipt, through the Foreign Office, of a translation of a Bolivian decree fixing the export duties on tin ores, leviable from January 1, 1907, at the following rates :—

Tin Ores.

	Bolivianos.†
If the quotation for Straits tin should be inferior to £100, the quintal of 100 lbs. Spanish shall pay	9·90
From £100 to £110	1·00
" 110 " 120	1·15
" 120 " 130	1·30
" 130 " 140	1·45
" 140 " 150	1·60
" 150 " 160	1·75
" 160 " 170	2·00
" 170 " 180	2·25
" 180 " 190	2·60
" 190 " 200	3·00
200 and above	3·50

* "Mining Journal," Nov. 3, 1906.
† Boliviano = 1s. 7d. (nominal value).

Tin Bars.

		Bolivianos.*
If the quotation for Straits tin should be inferior to £100, the quintal of 100 lbs. Spanish shall pay	-	1·50
From £100 to £110	-	1·60
„ 110 „ 120	-	1·75
„ 120 „ 130	-	1·90
, 130 „ 140	-	2·10
„ 140 „ 150	-	2·30
„ 150 „ 160	-	2·50
„ 160 „ 170	-	2·80
„ 170 „ 180	-	3·10
„ 180 „ 190	-	3·40
„ 190 „ 200	-	3·80
200 and above	-	4·20

In accordance with the quotation for Straits tin in Europe, the Minister of Finance will fix fortnightly and with strict observance of the preceding tariff, the rate of duty which the ores and bars shall pay, which rates shall remain invariable during the fifteen days notwithstanding that appreciable fluctuations in the quotation for Straits tin may take place in the meantime.

Companies working tin mines are exempt from the contribution of 3 per cent. on their net profit hitherto levied.

* Boliviano = 1s. 7d. (nominal value).

CHAPTER XII.

TIN DEPOSITS OF CORNWALL.

THE Cornish mines afford the best examples of tin-lode mining for the purpose of comparison, although too much reliance must not be placed on the experience gained in any particular district; still, the knowledge obtained by observation and comparison of tin deposits can be used when determining the value of newly discovered tin deposits in many parts of the world. Much has been written by Mr. Henwood and others on the Cornish tin deposits.

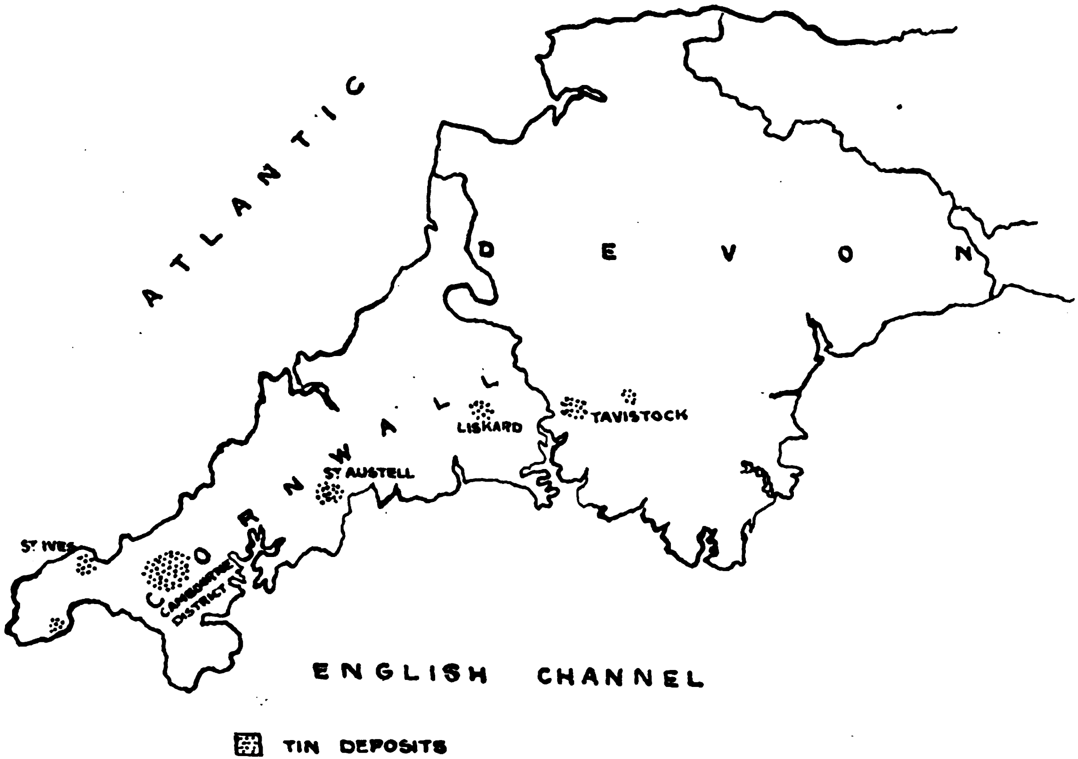
The lodes in Cornwall may be divided into the ordinary lodes and counter lodes. Tin-ore occurs disseminated through granites, elvans, and slates, as well as in minute veins in these rocks.

* Generally speaking, lodes which yield a mixture of the ores of tin and copper are wider than those which contain ores of only one of these metals. The lodes of Cornwall are wider in slates than in the granite, and their average width is greater within 100 fathoms from the surface than at any greater depth hitherto attained (subsequent developments at a depth have not borne out this statement in the Dolcoath mine). Henwood furnishes the following figures as the result of his investigations relative to the thickness of Cornish lodes :—

		feet	
Lodes yielding ores of both tin and copper	average	4·7	in width.
,, ,, tin ores - - - -	,,	3·0	,,
,, ,, copper ores - - - -	,,	2·9	,,
,, in granite - - - - -	,,	3·1	,,
,, in slate - - - - - -	,,	3·7	,,
,, at less than 100 fathoms deep -	,,	3·9	,,
,, at more ,, ,, ,, -	,,	3·3	,,

On passing from one rock to another, or from riches to poverty, the width of a lode frequently changes, but under ordinary circumstances a lode commonly maintains, approximately, its characteristic

* Henwood, Vol. V., "Trans. Royal Geo. Soc. of Cornwall," 1839.



MAP OF CORNWALL AND DEVON—SHOWING POSITION OF TIN DEPOSITS.

breadth. The directions of lodes in the different mining districts are not perfectly identical, nor are all those occurring in the same neighbourhood strictly parallel.

The mean directions of the lodes in different parts of Cornwall are given by Henwood as follows :—

St. Just - - - -	35° S. of E., N. of W.
St. Ives - - - -	8° S. of E., N. of W.
Marazion - - - -	1° N. of E., S. of W.
Gwinear - - - -	2° S. of E., N. of W.
Helston - - - -	16° N. of E., S. of W.
Camborne - - -	20° N. of E., S. of W.
Redruth - - - -	22° N. of E., S. of W.
St. Agnes - - -	22° N. of E., S. of W.
St. Austell - - -	13° N. of E., S. of W.
Caradon - - - -	18° N. of E., S. of W.
Tavistock - - -	9° N. of E., S. of W.

Their average bearing is about 5° N. of E., S. of W., a course which does not materially differ from that of the granite outcrops which at intervals make their appearance between Dartmoor and the Land's End, and also not unlike the course of a line drawn directly through the centre of the county. Lodes present as many flexures in their downward as in their horizontal direction, and vary in dip from an inclination of less than 45° with the horizon to 90°; the average being probably about 70°. Sometimes, although less frequently, lodes dip in opposite directions in different parts of their range. Both lodes and cross-courses dip more frequently towards the granite than away from it, and veins which maintain a nearly meridional direction are in Cornwall more highly inclined than those coursing more nearly east and west.

The most important tin-mining district in Cornwall is situated near Camborne, and the geological conditions of this district are both interesting and instructive. Mr. Donald A. MacAlister,* the Government Geologist of Cornwall, who has spent some years in the examination and mapping of the Cornish tin deposits, writes as follows :—

† The lodes shown in the cross-section may, as far as they have been explored, be divided into two groups ; those in the killas, on the north of the section, have produced mainly copper, while those in the granite mainly tin ; but they are all tin-copper lodes.

The lodes in this district appear to be influenced in the direction of their underlie by the elvans,‡ while it is interesting to note the remarkable change in the direction of underlie of the latter in glancing

* The author wishes to acknowledge the generous assistance given him by Mr. Donald A. MacAlister.

† "Trans. Royal Geol. Soc. of Corn.," 1903. A cross-section and some Notes on the Tin Deposits of Camborne, Cornwall, by Donald A. MacAlister.

‡ Robert Were Fox, "On Mineral Veins," "Rep. Corn. Poly. Soc. Falmouth," 1836, p. 96.

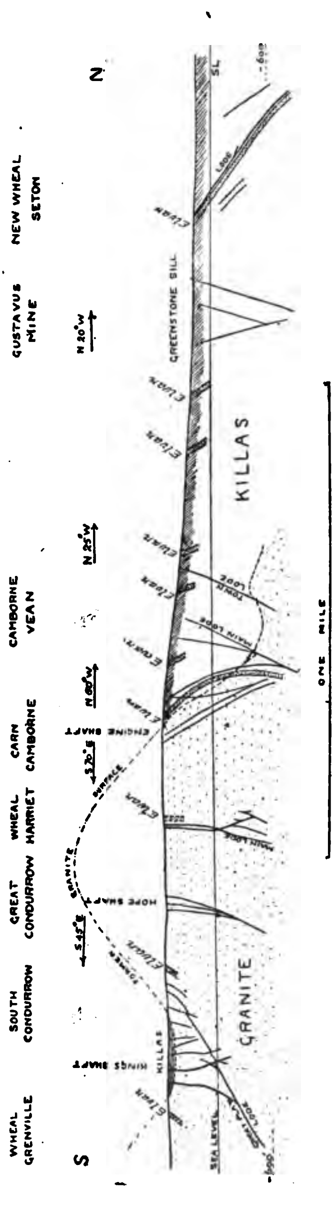


FIG. 24.—CROSS-SECTION OF THE CAMBORNE LODES ON THE WEST OF THE GREAT CROSS CO

from one end of the section to the other.* It has already been pointed out that "Granite, or its modification, elvan, occurs at or near all the localities where tin and copper ores so abound."† We may therefore say that in the Camborne area the lodes are ore-bearing fissures in the vicinity of elvan dykes ; ‡ from this point of view the ores must be regarded as having been a later product of the same magma which gave rise to the elvans.

General Geological Peculiarities of Camborne.—The main facts, so well known, may be epitomised as follows :—

The Palæozoic sediments and the intrusive sheets of greenstone were disturbed and metamorphosed in post-carboniferous times by granite,§ which has also penetrated them as sheet-like intrusions.|| It is certain that a great mass of sediment must have covered all the granite bosses now visible at the surface.¶ Shortly after the consolidation of the granite, the elvan dykes were injected from the same eruptive centre along planes of fracture, having a general bearing E. 30° N. Then followed the period during which lodes were formed. The greenstone is found at the surface in many places, and is the oldest of the igneous rocks.

Mr. Teall** has referred to the apparent sequence of eruption from basic to acid rocks.

Finally, cross courses, probably Tertiary, have faulted the district in a N.N.W. direction.

The Mineral Lodes.—The formation of the lodes was the latest phase of the plutonic activity.†† They have the same general bearing as the elvans, and are simple or bifurcating altered ore-bearing fissures

* De la Beche has already called attention to the apparent convergence of elvans in depths, as if derived from the same source ("Geol. Rep. Cornwall, Devon, and W. Somerset," p. 176). Some of the jointing in the granite appears to be subsequent to the intrusion of the elvans, but proof is as yet wanting. See "Trans. Roy. Geol. Soc. Corn.," 1901, vol. xii. part vii. p. 553.

† De la Beche, "Geol. Rep. Cornwall, Devon, and W. Somerset," p. 286.

‡ See "Plutonic and other Intrusive Rocks of West Cornwall in their Relation to the Mineral Ores," by Mr. J. B. Hill, R.N., "Trans. Roy. Geol Soc. Corn.," vol. xii. p. 588. Mr. Hill speaks of the coincidence of the general bearing of lodes and elvans with that of the tough-way joints in the granite.

§ Mr. J. B. Hill, of H.M. Geological Survey, has touched on the possible laccolitic nature of the granite. "Victoria County History," Cornwall, Geology section.

|| W. J. Henwood, "The Metalliferous Deposits of Cornwall and Devon," "Trans. Roy. Geol. Soc. Corn.," 1843, vol. v. p. 58.

¶ Estimated by Mr. J. H. Collins at 46,000 feet in thickness ("Geological Age of Central and West Cornwall," "Journ. Royal Inst. of Cornwall," 1881) ; and by Sorby ("On the Microscopical Structure of Crystals indicating the Origin of Minerals and Rocks," "Quart. Journ. Geol. Soc.," 1858, vol. xiv. p. 453) at 50,000 feet for the Carn Menelez granite, or about 9½ miles. The evidence for this very high estimate is, however, not conclusive, but it is sufficient to show that an enormous mass of sediment overlay the granite at one time.

** J. J. H. Teall, "Metamorphism in the Hartz and West of England," "Trans. Roy. Geol. Soc. Corn.," 1889, vol. xi. p. 221.

†† De la Beche, "Geol. Rep. Cornwall, Devon, and W. Somerset," p. 310.

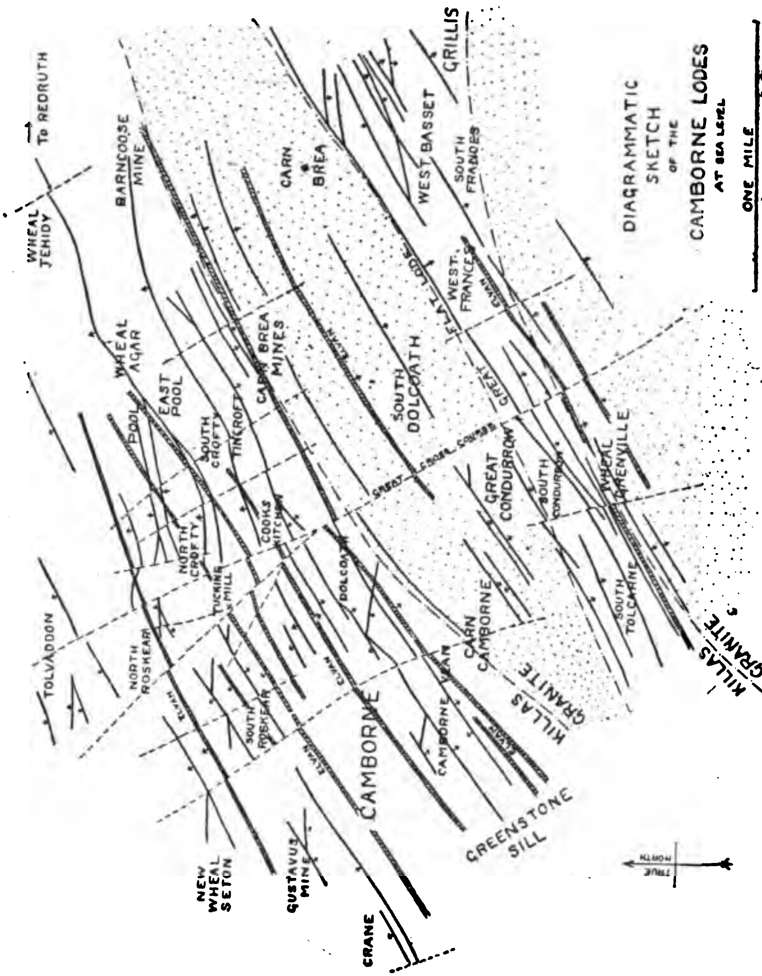

DIAGRAMMATIC
SKETCH
OF THE
CAMBORNE LODES
AT SEA LEVEL
ONE MILE
TRUE NORTH
TO REDRUTH
WHEAL TEHIDY
BARNCOOSE MINE
CARN BREA
WEST BASSET
GRILLIS
SOUTH FRANCES
WEST FRANCES
FLAT LODE
SOUTH DOLCOATH
CARN BREA MINES
WHEAL AGAR
EAST POOL
POOL
SOUTH CROFTY
TINCROFT
GREAT CROSS COURSE
GREAT CONDURROW
SOUTH CONDURROW
WHEAL GRENVILLE
SOUTH TOLCARNE
COOKS KITCHEN
NORTH CROFTY
TUCKING MILL
DOLCOATH
TOLVADDON
NORTH ROSKEAR
SOUTH ROSKEAR
CARN CAMBORNE
CAMBORNE VEAN
CAMBORNE
KILLAS
GRANITE
GREENSTONE SILL
NEW WHEAL SETON
GUSTAVUS MINE
CRANE
ELVAN

FIG. 25.

—frequently small fault-planes—in which the tin ore occurs as bunch or pipe-like deposits, due to infilling of the fissure (so forming a leader) and impregnation of country rock in its vicinity.*

The pitch of these ore bunches, in accordance with similar observations by Henwood,† in other districts appears to be easterly.‡ Sir Clement Le Neve Foster found in Wheal Uny that no part of the lode was absolutely barren, so that the pitch of the bunches could not be determined.

Various writers § endeavoured to give different ages to the Camborne lodes, but De la Beche assumed rather a certain period during which fissures would be open to fluctuating action.

Caunter Lodes.—In the Camborne district there are at least a dozen caunter lodes, forming a distinct fissure system, having a bearing approximately east and west. It seems that these lodes are really subsidiary fractures contemporaneous with the main lode fissures.|| (Fig. 26.) Although caunter lodes seem more prominent in the upper

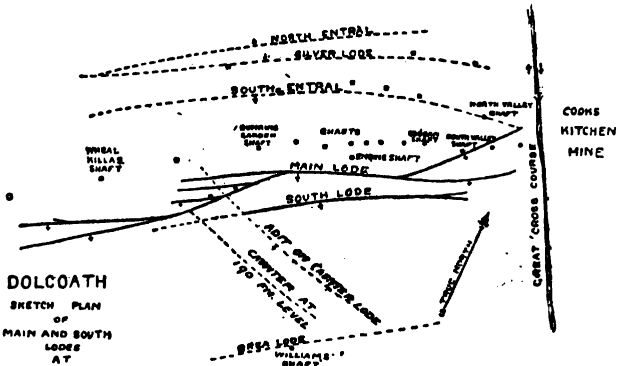


FIG. 26.

workings of mines, and in consequence of that position more often are copper-bearing, they have, nevertheless, their deep-seated tin-bearing representatives.¶ (Fig. 26.)

* De la Beche, "Geol. Rep. Cornwall, Devon, and W. Somerset," p. 317. Clement Le Neve Foster, "The Tin Deposits of East Wheal Lovell:" "Trans. Roy. Geol. Soc. Corn.," 1876, vol. ix. part ii. p. 8; "On the Great Flat Lode:" "Quart Journ. Geol. Soc.," vol. xxxiv., 1878, p. 640.

† "Trans. Roy. Geol. Soc. Corn.," vol. v. pp. 54, 87, 193.

‡ At Wheal Grenville they are very pronounced, and at Dolcoath the principal ore body is coincident with the line of junction of the bifurcating main lode, and the change in strike of the main lode near the caunter.

§ J. Carne, "Trans. Roy. Geol. Soc.," 1822, vol. ii. p. 49.

|| W. J. Henwood. "Trans. Roy. Geol. Soc. Corn.," vol. v. pp. 253, 327. See also Warington Smyth's remarks, "Physical Phenomena connected with the Mines of Cornwall and Devon:" "Brit. Assoc. Rep." (Plymouth), 1877, p. 8.

¶ Carn Brea, Wheal Basset, etc. The Dolcoath caunter lode has been intersected in the 220 fathom cross-cut, and Mr. Hosking (Tehidy Office) informs me that it is now a tin-bearing lode of meagre dimensions.

Epitome of General Facts, relating to the Mineral Contents of the lodes.—The copper ores of the ordinary copper-tin lodes occur at a higher horizon in the lode than the tin; hence, in a lode traversing granite and killas the copper is generally more productive in the killas than in granite, although neither ore is restricted to those rocks respectively.

When, as sometimes happens, leaders of tin and copper ores occur side by side, the width of the lode is greater than usual.*

Gozzans characterise the upper parts of copper lodes, while in tin lodes found outcropping in bared granite districts this peculiar feature is less pronounced or entirely lacking.

Tin was, however, extracted by the old miners from the backs of many gozzans.† The tin was probably concentrated by nature in the back of the lode by the leaching out of the unstable copper sulphides by weathering. Below the weathered zone various oxidised copper ores were found, below which came rich sulphides of copper, so much so that proportionately the tin present was reduced in many cases to an insignificant by-product, while in depth the copper died out, and the lode became a tin one. Henwood has already stated that the richest mines are those situated around the granite margins. (Figs. 27 & 28.)

Notes and Conclusions.—The question as to the origin of our mineral deposits in Camborne involves references both to primary and secondary enrichments. The literature on the subject is extensive.

The depositions of tin ore in the Cligga Head granite has been ascribed to pneumatolytic action.‡ Le Neve Foster, in a few classic papers, described the processes of deposition which must have gone on in our ordinary lodes.§

Primary Impregnation.—The elvan dykes were injected through fractures in the solid granite, from a magma within which was still viscous. At a later date those fractures connected with elvans were more likely to have penetrated to greater depths than those found away from elvans. Hence, after the consolidation of the granite, but closely following on the injection of the elvans,|| they must have drawn freely upon the sources of tin and copper,¶ whereas the fissures and

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* W. J. Henwood, "Address Roy. Inst. Corn.," 1871.

† J. H. Collins, "Sketch of the Geology of Central and West Cornwall:" "Geol. Assoc.," 1887, p. 20; "Origin and Development of Ore Deposits in the West of England:" "Journ. Roy. Inst. Corn.," 1892. Many of the lodes in Gwennap district had tin in the backs, while Carn Brea is an example in this district.

‡ Clement Le Neve Foster, F.R.S., "Trans. Roy. Geol. Soc. Corn.," vol. ix., 1878, p. 213. Mr. J. B. Scrivenor, M.A. (H.M. Geol. Survey), "Quart. Journ. Geol. Soc.," vol. lix., 1903.

§ "Remarks on some Tin Lodes in the St. Agnes District:" "Trans. Roy. Geol. Soc. Corn.," vol. ix. p. 185; "The Tin Deposits of East Wheal Lovell," *id.*, vol. ix. part ii. p. 8, 1876; "On the Great Flat Lode," etc.: "Quart. Journ. Geol. Soc.," vol. xxxiv., 1878, p. 640.

|| Near Gwinnear mineralisation is closely associated with the later of two sets of elvans. E. Dixon, "Summ. Prog. Geol. Survey," 1901, p. 25.

¶ See also the remarks of Mr. G. W. Lamplugh (H.M. Geol. Survey) in "Economic Geology of the Isle of Man:" "Memoirs of the Geol. Survey of United Kingdom," p. 489.

joint planes distant from elvans were not so easily, if at all, accessible to the metal-bearing solutions. Yet some veins have manifestly been open to action for longer periods than others, as the wide-banded "leaders," great thicknesses of "capels," or the lode breccias cemented by tin stone, peach, or quartz often testify.* Metalliferous solutions

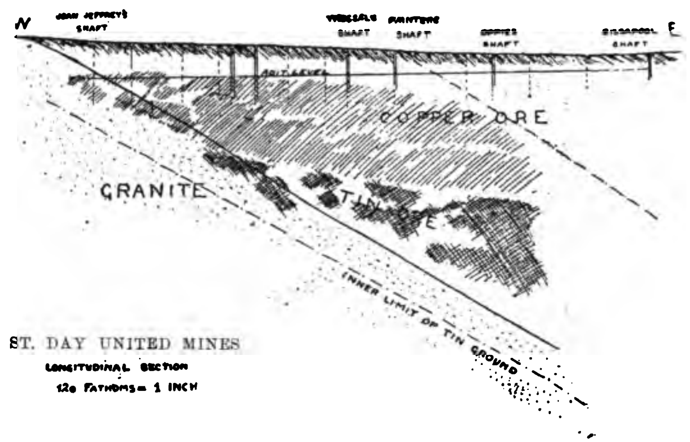

FIG. 27

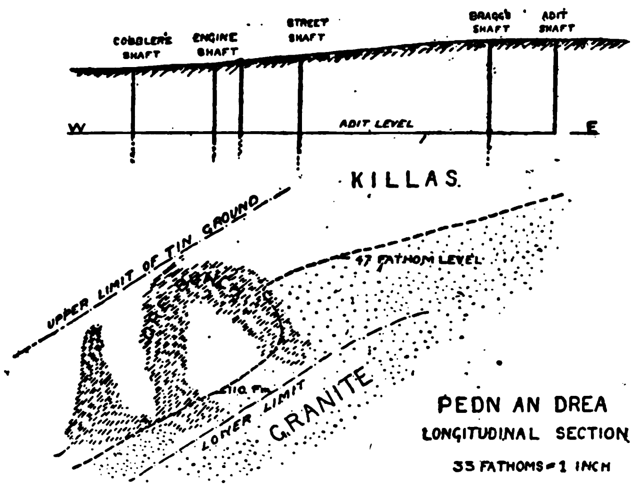

FIG. 28.

* De la Beche, "Geol. Rep. Cornwall, Devon, and W. Somerset," p. 339 *et seq.* See contribution by Dr. J. S. Flett (H.M. Geol. Survey), "Summ. Prog. Geol. Survey" 1902, p. 158.

from the interior of the granite mass* passed out through fissures towards its periphery, and impregnated the fissures mainly at some certain zone either in the granite or the killas,† according to the thermal or other physical conditions.

The case of the Great Flat lode, with its exceptionally long "pipes" of tin ore, is an example of prolonged infilling, due, possibly, to association with elvan. It has been described as a "contact deposit," but strictly speaking it is not so, for this implies "segregation" from the magma; in fact, it is only at the junction of the granite and killas in a very few places. In Wheal Uny, for instance, the lode in killas is at least ten fathoms away from the granite in some places, while in others it is wholly in granite (Fig. 24).

The question now arises as to what is the lower limit of the rich ore ground. The precise boundaries of this cannot be defined, since they are dependent on uncertain factors; but experience has shown that the lodes of this district are not uniformly productive to the deepest points reached by mining, and although the rich ore zone in the Camborne lodes is of great depth,‡ it is possible that exploration at deeper levels will not provide so extensive a field for mining operations as was met with in the upper levels. The change in the character of the ore from being coarsely crystalline in the upper levels to fine and compact in depth probably accompanies other changes in the lode. It is by no means suggested that the lodes become altogether barren, or that they lose their peculiarities as cassiterite veins; the occurrence of rich ore bodies in depth is not precluded. The works of Vogt and Lindgren § do not support any hypothesis which might suggest the total disappearance of the ore in the deeper parts of the lodes. It can only be inferred, then, that, generally speaking, the conditions assisting the deposition of cassiterite from its solutions were more favourable near the periphery of the granite than those nearer their source, and that solutions reaching the cooler regions near the contact deposited the whole of that cassiterite which they had managed to retain in the upward journey.

Allusion has already been made to the fact mentioned by Henwood that the rich mines are situated on the granite margins. There are two important points accounting for this peculiarity: one is that veins near

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* Professor J. H. L. Vogt, "Cassiterite Veins are genetically independent of the immediately adjacent country Rock:" "Problems in the Geology of Ore Deposits."

Mr. J. B. Hill states that the ores were possibly derived from the lower part of the granite itself (Plutonic and other Intrusive Rocks of West Cornwall in their Relation to the Mineral Ores:" "Trans. Roy. Geol. Soc. Corn.," vol. xii. part vii., 1901, p. 594).

Mr. J. B. Scrivenor says: ". . . all wholly blue tourmaline in granite modification has either been derived from orthoclase, or crystallised in its present state directly from the magma, whether fluid or vaporous" ("Quart. Journ. Geol. Soc.," vol. lix., 1903, p. 152).

† West Kitty, Wheal Kitty, Polberro, Wheal Vor, etc.

‡ Dolcoath is now over 510 fathoms below surface, the deepest workings being 300 fathoms in the granite. There are several elvan dykes in the sett.

§ "Trans. Amer. Inst. Min. Eng.," vol. xxiv.: J. H. L. Vogt, "Problems in the Geology of Ore Deposits," p. 671. Waldemar Lindgren, "Metasomatic Processes in Fissure Veins," p. 520.

the granite boss are more productive than those situated distant from it; the other is that denudation has resulted in the removal, not only of the superincumbent Palæozoic sediment, but also of a great part of the top of the granite boss, and with them a considerable portion of the most productive parts of the ore fissures, thus lowering the surface to the relatively deeper portions of the lodes (Fig. 24).

Various writers have assigned different times for the arrival of the tin and the copper in the lodes. Mr. Hill * concludes, however, that the ores are of "approximately identical age."

All the lodes are tin-copper, and belong to one system of fracture, so that there seems to be no reason for not assuming that differentiation took place from a common solution, whereby the cassiterite was concentrated mainly in one place, while the more soluble copper mounted to greater heights and was not so restricted in its occurrence.†

In the Camborne district it would be difficult to dissociate from the same origin the ores of wolfram, arsenic, zinc, lead, and silver.

Secondary Concentration.—It is generally admitted that secondary concentration of copper and the chemically allied metals takes place through the agency of ordinary underground waters. The papers of J. F. Kemp ‡ and H. F. Bain § include masterly contributions to our knowledge of the underground circulation of waters, while the paper of Van Hise is full of ideas of much interest.|| Mr. Kemp has already alluded to the dryness of mines at great depths, and although I have not the precise figures of the amount of water pumped in the past and at present, the evidence in such mines as Dolcoath, Carn Brea, Cook's Kitchen, East Pool, and Wheal Agar show that his observations are correct.¶

It seems that the denudation that has gone on since the lodes were formed is the process which determined the second concentration of sulphides. "Before the upper portion (of a lode) shares in the disintegration and denudation that are going on at the surface, it has already parted with its metalliferous contents, which have gone to enrich the lode below. Consequently, according to this view, the enrichment of lodes must be descending at a corresponding rate with surface denudation."** Professor Emmons has illustrated the processes

* J. B. Hill, R.N. (H.M. Geol. Survey), "Trans. Roy. Geol. Soc. Corn.," vol. xii. part vii., 1901, p. 593.

† Professor Vogt's "Cassiterite Veins," including primary copper. Arsenic may be included.

‡ J. F. Kemp, "The Igneous Rocks in the Formation of Veins:" "Trans. Amer. Inst. Min. Eng.," vol. xxiv.

§ H. F. Bain, "Relation of Ore Deposits to the Circulation of Underground Waters:" "Twenty-Fifth Ann. Rep. U.S. Geol. Survey," chap. iv.

|| C. R. Van Hise, "Some Principles Controlling the Deposition of Ores:" "Trans. Amer. Inst. Min. Eng.," vol. xxiv.

¶ I am informed by Captain Leonard Thomas that the waters in Levant mine come from above the 60-fathom level, and the mine is quite dry at the 338-fathom level.

** J. B. Hill, R.N. (H.M. Geol. Survey), "The Plutonic and other Intrusive Rocks of West Cornwall in their Relation to the Mineral Ores:" "Trans. Royal Geol. Soc. Corn.," vol. xii. part vii., 1901. p. 586. See also "Secondary Enrichment of Ore Deposits," Professor Emmons, "Trans. Amer. Inst. Min. Eng.," vols. xxii and xxiv., p. 463.

by which copper ores can decompose into soluble salts, migrate, and under suitable conditions regenerate with comparative ease.* Tin, on the other hand, and its accompanying vein constituents, are extremely stable, and practically impossible to alter by ordinary weathering processes. The existence of rich secondary copper ores may imply a fissure once admitting surface waters freely. Immense quantities of black, grey, and yellow copper ores were taken from the Basset lodes, seven or eight in number, to the 110-fathom level, but all of them ceased to be productive after that.† Black and yellow copper ores and native copper were also found alongside of tin in the middle lode (which is mainly in granite) at South Condurrow mine, but only to the seventy-fathom level, where the granite is rather rotten.

‡ *Vertical distribution of the commercially valuable ores in the Camborne Lodes.*—The lodes with a general bearing of E. 30° N. are parallel to the margin of the Carn Brea granite, and the information can be generalised for each series of lodes.

The South Crofty Series of lodes includes those lodes in Wheal Tehidy (on the east), Wheal Agar, East Pool, South Crofty, North Crofty, East Crofty, South Roskear, and Crane (on the west), situated along a line about half a mile north of the margin of the granite.

The average depth at which granite was first encountered in the principal mines in the foregoing list is about 170 fms. below the surface of the killas. On the west it is greater, and on the east less.

The lodes are characterised by good gossans. The copper ores were especially abundant from the higher levels (where they were oxidised) to varying depths in the different mines, but, generally speaking, 150 fms. below the surface marks the limit of occurrence in depth. Tin ore was worked from 80 fms. above the surface of the granite to the deep workings below. Wolfram was abundant (especially in East Pool) from 10 fms. above the granite surface to 10 fms. below, but in smaller quantities it has a wider range. Other minerals, occurring principally in the higher levels, include ores of cobalt, zinc, and uranium. Mispickel is a common ore.

The Dolcoath Series of lodes included those lodes in Barncoose (on the east), Wheal Druid, southern part of East Pool sett, Carn Brea, Tincroft, Cook's Kitchen, New Cook's Kitchen, Dolcoath, Camborne Consols, Camborne Vean and West Stray Park, etc. (on the west). The principal mines are situated along the margin of the Carn

* S. F. Emmons, "The Secondary Enrichment of Ore Deposits," "Trans. Amer. Inst. Min. Eng.," vol. xxiv.

There was an instance of migration of copper in actual process at Great Condurrow mine, where, at the 140-fathom level, a stream of water, with copper sulphate in solution, issued from the lode and precipitated copper on the metal-work in the shaft. Water, at a temperature of 102° F., was also met in North Roskear at the 160-fathom level, indicating energetic action.

† There was a period of poverty lasting seventeen years at Dolcoath mine before the rich tin was discovered below the rich copper ore which had been worked out.

‡ D. A. MacAlister, "Summary of Progress Geological Survey," 1903.

Brea Granite. The main lodes first encounter the granite at about 100 to 130 fms. below the surface of the killas (on the west of Dolcoath it is over 220 fms. below). The main lodes all have good gossans. The copper ores in Cook's Kitchen and Dolcoath were very rich down to about 200 fms. below the surface, but in the former mine copper continued to occur down to 360 fms. below the surface, but was not so valuable in depth. Tin ore in Dolcoath was especially abundant from 180 fms. below the surface to near the bottom of the mine, which is now down to the 485 fm. level, where the lode is 42 feet wide and contains about 25 lbs. of black tin per ton. In Carn Brea the lodes were very poor in tin in the deep levels, although tin occurred in greater or less quantity right up to the surface before it was worked out. Exceptional ores for this district were those of silver, which occurred in the "Silver Course Lode" in Dolcoath at a comparatively shallow level.

In the Great Condurrow Series, situated further south and consequently entirely in granite, the tin and copper ores were mixed, but copper was not abundant below the 200 fm. level. Tin ore occurred in the lodes from the surface downwards.

The Great Flat Lode Series includes Wheal Basset (and other mines on the east), West Basset, South Frances, Wheal Frances, West Frances, Wheal Grenville, South Condurrow, South Tolcarne, and several trials (on the west). On the west the Flat Lode Series is practically wholly in granite, and lies in a valley situated between the Carn Menelez Granite and its Carn Brea outlier. In going eastwards the granite is found at a greater depth, and the Flat Lode itself passes out of the granite into the killas and lies parallel to, and not far removed from, the granite surface. The more or less vertical lodes which intersect the Great Flat Lode pass into the killas eastward. The Flat Lode has never contained much copper, but in South Condurrow and Wheal Basset copper has been found in small quantities (as "native," oxidised, and sulphide ores) to 80 fms. below the surface. Generally speaking, it is a wide lode of low grade tin ore. The more or less vertical lodes which intersect the Great Flat Lode were mainly copper. In Wheal Basset these lodes, eight or nine in number, contain copper to a depth of 150 fms. and are poor below, although still in killas at that depth. On the west, where the vertical lodes are in granite, they are not copper-bearing to such depths.

The Great Flat Lode.—Sir Clement Foster * states that a part of the lode left standing in Wheal Grenville is 1 to 8 feet in thickness, and in South Condurrow the tin-bearing part is 5 or 6 feet in thickness, but that the total width including the barren capel in either wall of the lode is 12 to 20 feet. In West Basset the lode and altered country rock at the 140 fm. level are 40 to 50 feet in thickness. R. H. Thomas † observes that in Wheal Uny this same lode varies from

* "On the Great Flat Lode." Q. J. G. S. (1878), vol. xxxiv, p. 640.

† "Some observations on the Great Flat Lode." R. Corn. Poly. Soc. (1886), p. 184.

4 to 10 feet in thickness and in one place near a cross course the lode is 72 feet wide.

The following examples of the variation in width in the different parts of a lode are cited by Henwood.* In Tincroft Mine some parts of the Highburrow Lode are but 3 or 4 feet wide whilst others are 30 to 40 feet. The Engine Lode at (Wheal Crofty) North Koskear varies from 1½ to 18 feet. The Main Lode in Wheal Vor varies from 3 to 30 feet. The Bor Lode in Polladras Downs varies from an inch to 4 feet. In Nangiles the lode reached a maximum width of 30 feet.

Levant Mine (St. Just).—The operations are almost entirely confined to the parts of the lodes which intersect the greenstone sill fringing the coast. The granite plunges beneath the killas in a north-westerly direction at an angle of 50°. Beyond the killas (a thickness of over 100 fms.) the sill of greenstone underlies in the same direction as and approximately parallel to the surface of the granite. The lodes striking from the granite in a north-westerly direction cut across the granite and the greenstone approximately at right angles. Mining operations, although at present almost entirely confined to the greenstone "country," do not appear to have revealed its outer boundary. The lodes are unproductive or very poor in the granite for both tin and copper ores, but they get more productive in passing from that rock into the killas and greenstone beyond. Although there seems no reason for supposing that the greenstone in any way contributed in localising the productive belt, it is worth noticing that the ore ground seems to be persistently associated with that rock from quite near the surface to the deep levels (338 fm. level). For a great distance the ore ground is, practically speaking, coincident with the greenstone, but it should be regarded as bearing a definite relation to the surface of the granite, and the ore ground actually removed in mining operations is seen to be roughly parallel to it.

Gurlyn Consolidated Tin Mines (Cornwall) Ltd.—Marazon District.—This company hold the following properties :—The Gurlyn, Nantarras, East Trevelyn, Penberthy Croft, Enny's Wheal Virgin, Wheal Kidney, Tindene and Retallack Tin Mines.

This important group of mines is situated in the pre-Devonian slates of West Cornwall. In this area the sedimentary rocks present all the characteristic phenomena of contact alteration by proximity to the Godolphin granite mass, and petrographical examination of the rocks in the vicinity of the mines shows them to have been affected considerably by vapours emanated during the final phases of consolidation of the granite intrusion. It is during this period that the deposits of tin-ore were produced, and it is for this reason the occurrence of the mines in the metamorphic area is emphasized. The fact of the occurrence of these mines in the killas area in no way militates against the continuance of the deposits to great depths. On the contrary it is rather an advantage than otherwise, as killas is an easier rock to break than granite.

* Tr. Roy. Geo. Soc. Corn. (1843), vol. v., p. 240.

Work is being actively carried on at the Gurlyn mine, and a ten-stamp Californian mill with complete dressing plant is in course of erection. A Speery vanner will be employed on the treatment of the pulverized ore. This is the first time this machine has been used in Cornwall.

The whole series of the mines in question show evidences of a large amount of work having been carried out in the past, and probably embrace the finest series of continuous ore bodies at present unworked in Cornwall.

In the St. Just district there is a variety of schorl rock locally known as "ramp." A common type is a druse aggregate of quartz and granular and acicular tourmaline crystals, the texture varying from compact to coarse. Formerly, in East Levant Mine, there was evidence that at least one tin lode intersected a course of "ramp," which thus appears to be an older formation.

Small quantities of detrital tin ore deposits are still known to exist, but we can now say, as Mr. Henwood said nearly 20 years ago, that having been wrought from remote antiquity they are now nearly, but not quite, exhausted.

These deposits have been admirably described by various observers; Mr. Henwood describes them with more or less detail.* In all of these the richest "tin ground" was found resting directly on the solid rock, beneath the "shelf" or "bed rock." This was usually covered with several alternating layers of peat or vegetable-mould, sand, and gravel. Sometimes an upper and poorer layer of tin ground occurred, resting in a "false-shelf" not far beneath the surface; the components of this upper layer being, as Mr. Henwood observes, less rounded than those of the true tin ground. He also remarks that the components of the tin ground generally are more rounded in proportion to their distance from their elevated source, and furthermore that the more elevated tin grounds resemble in mineral character the rocks upon which they rest, while those nearer the mouths of the valleys have no resemblance.

The detrital tin ore of the West of England occurs as crystals, pebbles, sub-angular masses, and water-worn grains of cassiterite, sometimes associated with similar fragments of iron pyrites and other "heavy" metallic minerals, and occasionally even with small nuggets of gold.† The cassiterite is sometimes attached to fragments of granite or slate, or to pieces of quartz, felspar, or other veinstone, but more commonly it is free from such attachments. In any case, it forms but a very small proportion of the "tin ground," rarely exceeding 5 per cent. of its mass, and often not so much as one-tenth of 1 per cent.

It would be impossible to describe in detail all the mines in Cornwall. The chief districts where tin mining is now carried on are Camborne, Redruth, St. Ives, St. Agnes, St. Austell, and Levant.

With regard to the future of tin mining in Cornwall naturally opinions differ. The author has come to the conclusion, after examination of several of the old mines in Cornwall, that undoubtedly there

* J. H. Collins, "Origin and Development of Ore Deposits."

† See "Jour. Roy. Inst. Corn.," 1873.

are still good openings for the successful employment of capital. Modern methods of mining and tin dressing, together with the high price ruling for tin, would make for success, and it is by more extensive exploration that the old mines will pay. There have in the past been several periods of depression in Cornwall when the price of tin ruled very low and fresh capital was unobtainable. It was during these periods that some old mines were forced to close down which would return handsome profits to-day if properly equipped.

* TIN STATISTICS FOR CORNWALL, 1906.

1906.		Computed Tons.	Average price per ton.			Values.			Average Price of Metallic Tin per Ton on day of Ticketing.		
			£	s.	d.	£	s.	d.	£	s.	d.
January	1 ...	183¾	94	3	2	17,772	5	0	195	15	0
	15 ...	246½	97	12	6	24,066	10	0	170	0	0
	29 ...	202½	96	9	2	19,532	17	6	167	0	0
February	12 ...	237	96	15	10	22,939	18	9	166	10	0
	26 ...	207¼	97	16	1	20,270	1	10	165	2	6
March	12 ...	252	97	6	7	24,527	6	3	165	0	0
	26 ...	216¾	99	3	3	21,494	2	6	167	10	0
April	9 ...	232½	101	11	7	23,617	3	9	171	10	0
	23 ...	204	104	11	0	21,327	13	9	176	0	0
May	7 ...	255	113	7	6	28,906	15	0	191	15	0
	21 ...	213¼	107	11	9	22,943	2	6	185	0	0
June	6 ...	254	105	12	7	26,829	16	3	179	0	0
	18 ...	202¼	104	7	4	21,108	0	0	177	0	0
July	2 ...	254¾	102	14	0	26,163	7	6	177	0	0
	16 ...	210	97	13	9	20,514	8	9	168	10	0
	30 ...	232¼	98	15	5	22,939	7	6	172	10	0
August	13 ...	202¼	104	9	10	21,133	12	6	183	5	0
	27 ...	241	104	19	9	25,302	17	6	184	0	0
Sept.	10 ...	185	105	11	4	19,530	0	0	184	0	0
	24 ...	228½	106	8	0	24,312	11	3	185	5	0
Oct.	8 ...	191½	113	5	10	21,695	6	3	195	10	0
	22 ...	241½	113	19	8	27,528	7	6	197	10	0
Nov.	5 ...	191½	114	5	11	21,888	1	3	197	5	0
	19 ...	242	113	2	1	27,381	0	0	195	12	6
Dec.	3 ...	187½	114	4	0	21,412	15	0	197	5	0
	17 ...	258¾	113	10	5	29,373	1	10	197	5	0
	31 ...	195	114	4	1	22,270	1	3	193	12	6
Total	...	5,973¼	—			626,780	11	2	—		

Since 1905 very considerable interest has been taken in reopening the Cornish mines, several large Limited Liability Companies have been

* "Mining Journal," London, 12th January, 1906.

floated, the old cost-book methods having fallen into disuse. In several instances sufficient capital has been subscribed to thoroughly test the lodes at a depth. The machinery being installed is of a most up-to-date description, and upon the result of these ventures the future of tin mining in Cornwall will largely depend.

Thirty companies were registered to reopen and work the Cornish mines in 1906 having a total nominal capital of £1,184,700.

CHAPTER XIII.

TIN DEPOSITS OF NORTHERN NIGERIA, TRANSVAAL, SWAZIELAND, CONGO FREE STATE, JAPAN, GREENLAND, FINLAND, CHINA, KOREA, AND SIBERIA.

TIN DEPOSITS OF NORTHERN NIGERIA.*

THE occurrence of tin in Northern Nigeria has been known for many years past by the presence of quantities of small faggots of very pure metal in the native markets, which occasionally found its way down to the coast. Until three years ago, when the territory was transferred from the Royal Chartered Niger Company to the Colonial Government, the country away from the valley of the Niger and Benue was practically unknown, but as soon as the Government had satisfied themselves as to the safety of travelling in the territories the Niger Company despatched an expedition for the purpose of a geological examination of the country east of the Niger, and if possible to locate the tin-bearing areas.

The tin was eventually traced to the Province of Bauchi, some 600 miles to the north-east of Lokoja, the then headquarters of the Government, situated at the confluence of the Niger and Benue rivers.

Further prospecting located the stanniferous area to the outliers of the Gura Mountains, a small range known as the Naraguta and Shere Hills, in the Badiko district of that province. The tin was found as coarse and fine-grained alluvial stream tin in the beds and banks of the River "Gimpy" or Kogin-Delume (this translated from Hausa is Kogin-River and Delume-Tin).

The geology of the area is composed of granites, igneous intrusions of diabase and porphyry forming the prominent peaks of the hill range. Near the river a coarse grey gneiss forms a contact with the granite, both of which rocks are traversed by lenticles and gash veins

* This account was written for the author by Mr. R. C. Nicolaus, December, 1904.

of quartz, and several small igneous dykes cross diagonally the general strike of country, which is north-east and dips west.

The stanniferous area has now been narrowed down to approximately 25 square miles, and although the stream tin has so far only been prospected near the river there is abundant evidence to show that the source of the tin supply comes from a stockwork formation in the granite at the slopes and at the base of the foot-hills.

A somewhat remarkable feature of this deposit is that a considerable quantity of metallic tin has been discovered under the river banks during prospecting operations. It is found in small grains and nodules about the size of a bean, and its surface very thinly coated with a film of oxide, the metal being very pure, containing only a trace of iron; it is very ductile and emits on crushing the peculiar tin cry. Its mode of occurrence in the gravels and associated with coarse grains of stream tin at a depth of some 15 feet under the surface does not allow its genesis being determinable, but it can without a doubt be put down as "native tin," a mineral up to the present of very rare occurrence.

The stream tin contained in the gravels is generally coarse, the average product so far obtained by tests being 35·66 lbs. per ton of alluvial. The procedure of the native in securing this black tin is as follows:—

The washers (Hausa men and women), usually working in gangs of three or four, wade into the river, tributary creeks, and gullies, generally at or near some shallow rapids, and loosen the gravel under water with a short hoe-like implement and scoop it into large calabashes about 18 inches to 24 inches in diameter. As soon as sufficient gravel is collected (about 30 lbs.) it is washed and the resulting rough concentrates placed in a smaller calabash, 6 inches to 8 inches in diameter, and thoroughly cleaned (nearly all the fine tin being lost), the resulting black tin, containing 60 per cent. to 65 per cent. metal, is sun dried and packed in bags and skins for transport to the smelting furnaces, 18 miles distant.

A gang of four will average in an ordinary day's work 80 lbs. to 1 cwt. of clean black tin.

The local market value of this black tin works out at £15 15*s.* per ton.

The black tin is usually smelted in various parcels on a royalty basis exclusively by members of a family who hold the process a great secret. Only three smelting furnaces are in use, and are only capable of turning out about 2 cwt. a day each. They are built of well-puddled clay, and are 3 feet 6 inches diameter, having at the back four tuyère holes conducting the blast from primitive sheepskin bellows to the hearth. The tin is reduced by charcoal only, and runs through a channel 2 feet 6 inches long and 4 inches broad into a catch-pot, from where it is ladled by small gourds or calabashes and poured.

The cast tin takes the form of 12-inch long strings of about $\frac{1}{8}$ inch diameter, which are produced by pouring the molten metal on to an 18-inch high semi-circular bank of clay which is perforated by dry guinea-corn halms.

The analysis of the metal is as follows :—

Analysis of tin bar received :

Tin	99·400
Iron	·520
Lead	·015
Loss	·065
	100·000

Very little tin is lost in the process, as all slags are carefully collected, re-crushed, washed, and concentrated, and the product added to the next smelt.

Tin Deposits in the Transvaal.

Some tin lodes and alluvial have been discovered in the No. 373 District of Pretoria. Harry D. Griffiths, in a report on the tin deposits, writes as follows :—

"*Bushveld Tin Mines Ltd.*

"*Geology.*—The rocks encountered on your property are almost exclusively red granite. The granite is of a very coarse variety, with a great development of orthoclastic felspar, and occasional presence of tremolite or actinolite. Plagioclastic felspar is either rare or totally absent. The granite forms practically a boss, running north and south, and limited to the east by a wide volcanic intrusion running north and south along the eastern boundary of the property, and covered by a great thickness of sand and detritus to the west. Grey granite occurs in sporadic patches on Enkeldoorn. To the north volcanic intrusions are again in evidence, and to the south and south-west secondary measures are obtained. In the centre of the boss the granite contains a system of lodes or fissure veins running slightly east of north, in the vicinity of which the granite is of a finer structure, although its components appear the same. In addition to the main system of lodes, several cross lodes are encountered on Enkeldoorn and Zustershoek.

"*The Lodes.*—The lodes consist of a series of almost parallel fissure veins, whose outcrops can be followed for considerable distances. These are most conspicuous on Enkeldoorn, but can be found again on Rietfontein, and can be followed almost continuously into Zustershoek. The strike appears most regular, and no dislocations are apparent. The cross lodes, which bear similar characters, do not appear to have dislocated the strike of the lodes, or *vice versâ*, and it would appear, therefore, that they are contemporaneous with one another.

"The lodes have a slight dip to the east, the maximum inclination noted being 82 degrees from the horizontal.

"One of the lodes striking north and south has been opened out by means of trenching for a considerable distance ; this has been called so far the 'Main Lode,' and for the sake of simplicity this denomination

will be retained. It shows the walls of the lode to be well defined with fine-grained granite hanging and footwall. The matrix of the lode is composed of quartz and orthoclase, fine-grained and generally of a light colour, with rare flakes of mica (muscovite). Its structure is pegmatitic, and hence the matrix has generally been called pegmatite, although, owing to the fine-grained structure in depth, it should be more properly denominated as aplite. The ore body shows floors of horizontal joints at close intervals without signs of lateral displacement of the walls; and the enclosing granite shows joints mostly at right angles to the course of the lode. Disseminated in the mass are found pyrites and cassiterite. The pyrites, as shown by analysis, contain a small amount of arsenical pyrites. The cassiterite is pretty pure, but encloses a small proportion of pyrites. So far the presence of titaniferous iron and of tungstate of iron (wolfram) has not been detected, although they may make their appearance in depth. The presence of these in the ore would render the roasting of the cassiterite necessary before smelting. The presence of wolfram in appreciable quantities would probably be an additional source of revenue, as its price has risen considerably of late, and its special extraction would not add much to the cost of treatment. The 'Main Lode,' so far as exposed in numerous trenches, is generally well defined close to the surface, and shows a total thickness of as much as 12 feet. In some trenches the lode is split up into stringers separated by fine grained country rock, but having a distinct tendency to unite in depth. In places the outcrop of this lode shows a width of over 20 feet. The trenches have exposed the reef over one mile, and three small shafts have attained a depth of 50 feet. Wherever this lode has been touched it has been found tin-bearing, and in some instances of great richness.

"*Cross Lodes.*—To the south of the camp on Enkeldoorn two well-defined cross lodes are encountered, the first being some 460 yards south of the spruit, and the second some 250 yards further. The first one shows a powerful outcrop of a width of about 12 feet, and it strikes 28 degrees S. of E. magnetic. Where it crosses the main lode and first east lode the junction is well exposed, and there is no dislocation apparent. This lode is again obtained due east of the camp in the road, where it is apparently over 4 feet in thickness. Continuing its course to the east, it finally abuts against the large elvan dyke, which cuts it off. The second cross lode has also a regular strike, but its outcrop does not show so prominently as the first.

"In the southern portion of Zustershoek occasional outcrops towards the spruit give evidence of the occurrence of another cross lode. North of the camp, and 6,000 feet south of the Enkeldoorn northern boundary, two outcrops of cross lodes occur within 100 yards of each other. The outcrops are very wide where they peep out from under the overlying sub-soil.

"As far as is evidenced, the lodes appear to be true fissure veins, and their permanence in depth assured. The gossan or iron capping which is almost invariably found in metalliferous lodes is well in evidence with each of the lodes.

"The number of lodes and cross-lodes as above stated is as far as can be ascertained for the present, and cannot be taken as representing everything in the shape of lodes that may occur on the property. Where the bed rock is exposed on high ground the outcrops can be well followed, but a large portion is covered by surface drift, which will necessitate extensive prospecting.

"The presence of tin in most of the samples taken from the capping of lodes and cross-lodes is a most encouraging feature.

"*The East Elvan.*—Following as near as possible the strike of the main lode, and east of the camp beyond the most easterly cross-lode, a huge elvan dyke occurs. Its thickness to the west has not been ascertained. The strike can be followed almost all along the eastern boundary of Enkeldoorn, and on Zustershoek it is again well in evidence at the most easterly beacon. The dyke, judging from surface samples, appears to be composed of a confused mass of felspathic rock and serpentine. The felspar rock shows orthoclase blended with actinolite, both being coarse in texture, and is probably derived from the breaking up of the granite with alteration of its constituents. Quartz appears in rounded grains, and is most abundant in the vicinity of the hematite body, where the rock strongly resembles quartz porphyry. Serpentine is abundant, but whether it constitutes the bulk of the elvan, my observations have not yet established. It is of a dark green colour, with enclosures of garnet rock and specks of muscovite and pyrites. Occasional enclosures of titaniferous iron are encountered, as well as altered felspar and occasional quartz stringers. The rocks of the elvan are apparently greatly mixed, and will require a more lengthened study than I have been so far able to undertake. The fact of the cross-lodes stopping short against the elvan mould shows the latter to be of younger origin than the lodes. The elvan contains well away from its western edge a body of hematite. This has been opened out in a shallow shaft on Enkeldoorn and shows a thickness of 12 feet. Both walls of the body are well distinct, and the dip is 80 degrees to the east. The hematite is again exposed on Zustershoek in a trench. At this point the width has not been ascertained, and being mixed with a quantity of quartzose matter it is not so rich as in the first shaft.

"It is probable that the dip of the hematite body corresponds to that of the elvan, and in that case, so far as your properties are concerned, the elvan would not have any detrimental effect in cutting off the lodes in the dip.

"*Alluvial Tin.*—The western portion of Enkeldoorn is composed of low-lying and flat country, and covered over by a great thickness of detritus. This extends on the gentle slope of the rise to the outcrops of the lodes. On the slope the thickness of the drift averages 3 feet, whereas on the flats I feel certain that a very much greater thickness will be obtained. Samples of the drift gave in every instance the presence of cassiterite, and should prove payable if worked on a large scale."

In the engineer's report of 31st July, 1905, a total of 1,341 feet has been sunk and driven in this property with encouraging results.

Tin Deposits of Cape Colony.

Kuils River Tin Mines.—They are 12½ miles from Cape Town and cover an area of 5,037 miles. The country rock consists of granite which belongs to Cape system. The hills are traversed in a north and south direction by bands of greisen, with closely associated quartz lodes dipping to the east.

The granite is grey passing into a syenite. The greisen is characterised by a large proportion of mica and the quartz constituents are mostly fine grained. The quartz is generally white and compact, showing occasional patches of mica, and containing minerals in the shape of cassiterite and wolfram.

Near the surface the lodes dip to east at an angle varying from 25 degrees to 35 degrees from the horizontal.

As far as ascertained the chief source of the minerals is the quartz-reef, although the greisen shows mineralization. The decomposed granite intervening between the band of greisen and quartz appears to be impregnated in the vicinity.

Alluvial Tin.—This was first discovered in the creek in Langverwacht. The chief ascertained source of the alluvial tin is a loose breccia of angular fragments of lode quartz cemented together by kaolinised matter containing cassiterite in angular and sub-angular pieces as large as 3 in. cubes.

This breccia rests on more or less impure kaolin, the result of the decomposition of the country rock ; this decomposition is very extensive.

The breccia in parts carries considerable quantities of cassiterite. Mr. H. D. Griffiths, in his report in June, 1905, stated that :—

"I estimate therefore the total yield of the alluvial on the properties cannot be less than 25,000 tons of cassiterite having a gross value of £2,250,000."

Swazieland Tin Field.

This field was discovered by Mr. Ryan in 1889.

The geological features of the tin district are briefly described as follows :—*

Granite bosses flanked by metamorphic rock intersected by elvan dykes, diorite and rhyolite. The tones of quartz and hornblende-schist and steatite may be observed striking N.N.W. by S.S.E. and dipping slightly west, being apparently of a much older formation than the "Golden Beet" resting uncomformably a few miles north.

* Chemical and Metallurgical Society of South Africa.

The following is the order in which the intrusive rocks occur :—

1st. Intrusive granite which has undoubtedly tilted the schists.

2nd. Elvan dykes striking N. and S. and dipping at an angle of 30 degrees west.

3rd. Diorite dykes intersecting the formations in all directions.

4th. Rhyolite cutting through the formations in a N.E. direction. This is undoubtedly contemporaneous with the Lebombo upheaval.

Elvan dykes vary in width from a few inches to many feet, and are composed of felspar, quartz, mica, and hornblende, in which crystals of cassiterite, garnet, monazite and tourmaline are contained. Molybdenite and corundum are also found in the schist which the elvan dykes have cut.

Deposits.—"The Stream Tin" in alluvial deposits originates from the erosion of the elvan dykes before mentioned, and is deposited in three beds as follows :—

1. Oldest deposits yielding ¼ per cent. tin.
2. Yielding ½ per cent. to 1 per cent. of tin.
3. Yielding ¼ per cent. of tin.

The average thickness of these beds is 4½ feet through; the Lower Embabaan and Usutu Rivers now being prospected contain beds of considerable thickness.

The supply of labour is good, and the water supply from the Little Usutu River and the Babaan River large and unfailing.

Assay value of the tin ore is 60 per cent. of metallic tin for about 10 per cent. of the quantity raised, and 72 per cent. for the balance.

The chief mining camp is at Embabaan about 5,000 feet, and the climate is considered very healthy.

Tin Deposits.—Congo Free State.

Tin has been found both in the alluvial drift and in ledges on the Tanganyika Concessions in the Congo Free State, about latitude 10° 20′, south longitude 25° 13′ each, and found at intervals for a distance of 60 miles north-west along the valley of the Lualaba River.

The tin ore discovered all lies north of the southern boundary of the granite belt, which extends through the country in direction about E. 15° north, which boundary is in latitude and longitude above mentioned at that point.

The most important of the tin discoveries so far made is the Busanga Tin Mine, situated at latitude 10° 12′ and longitude 25° 13′ east, north of the Lufupa and west of the Lualaba, the centre of this property being 1,200 yards N.W. of the junction of these two rivers.

* *Busanga Ridge.*—This ridge extends in a N.N.E. direction parallel with the Lualaba River. It is cut by several watercourses, which are dry except during the rainy season.

At its southern end the height of the ridge is 180 feet about the Lufupa, and distant about 900 yards from that river. The ridge at the northern end of the cassiterite area is 270 feet in height above the Lualaba and distant 1,060 yards west of that river, with slope down to the river. The surface of the ridge is covered with loose ground composed of schist, gravel and quartz fragments.

The cassiterite is distributed through this loose ground from the surface over about nine-tenths of the area down to the depth of 7 feet in places, but in one-tenth of the area the cassiterite stratum is covered by a clayey wash to a depth of from 6 inches to 17 feet.

Quartz Reefs.—Twenty-two cuttings from 6 to 10 feet in depth have exposed quartz reefs, widths of from 1 to 25 feet. These reefs stand nearly vertical, with strike generally parallel to that of the ridge, having good walls. In all of these reefs some cassiterite is found, mostly in a few inches of the quartz near the walls, but in a few instances it is found diffused through the quartz of the reef to some extent, but the quartz reefs so far exposed have not shown a percentage of cassiterite which will pay to mine for the ore. The great body in the aggregate of cassiterite contained in the gravel of the surface of the ridge has undoubtedly come from the outcrops of quartz reefs which have become disintegrated by long exposure to the weather, and the quartz fragments now form a considerable portion of the bed of gravel which covers the surface of the ridge and conceals the reefs from which the cassiterite and quartz were denuded.

The cassiterite found in the gravel of the ridge is in the same form as seen in the quartz reefs which have been exposed. The stream tin found in the watercourses leading from the ridge shows signs of having travelled; the further away from the cassiterite areas the more rounded are the rolled fragments of tinstone.

The Kasonso Tin Mines are situated in the Kasonso Hills, Congo, Africa, and consist of ten contiguous mining locations which conjointly form a property 12 miles in length with widths of 4¼ miles for a distance of 5 miles of the south-west portion, and 3½ miles for the remaining 7 miles of the north-east portion of the property, forming an area of 45¾ square miles of 29,280 acres. The centre of the property is about latitude 9 degrees and 24 minutes south, and longitude 25 degrees and 48 minutes east.

The Kasonso Hills are a distinct range of rolling hills extending north-east and south-west 18 miles in length and 4 miles in width, rising at the highest point to 900 feet above the level of the surrounding country and 2,900 feet above sea level. The country rock of the hills is sandstone, formation regular, the sandstone reef running with the strike of the hills. Granite outcrops near the base of the south-east line of the hills, near the centre of the south-eastern line of the mining property.

* Tanganyika Concessions Report, July, 1906.

Lodes.—The tin lodes consist of a series of quartz vein running, so far as can be observed, from uncovered croppings regularly with the sandstone reefs. The lodes can be followed almost the entire length of the property by the permanent quartz outcrop, or by quartz drifts covering the surface, the disintegration of the reefs. Black tourmaline and tourmaline in fine crystals, sandstones more or less altered and schistose, and mica schist rocks and boulders are to be found scattered over the surface with the quartz drift along the line of the tin bearing lodes.

The outcrops of the quartz lodes are mostly covered by the drift, and no sinking has been done upon the lodes to determine any of their extents or values, but in trenching across the reefs and sinking prospecting holes to find the depth and value of the alluvial ground, the lodes have been cut in many places for from 5 to 10 feet below the surface, showing the existence of parallel lodes and their continuity for several hundred feet from 2 to 4 feet in width, and giving evidence of permanency in depth. In most places where cut by this prospecting work the solid reefs have shown considerable cassiterite, and the drift from all the trenches and holes sunk adjacent to any of the lodes average especially well in cassiterite when panned.

At the Kasonso Tin Mines the total average over 12,950 yards prospected yielded :—

Cubic Yards.	Average Value per Cubic Yard.	Amount of Tin Ore.
1,132,962	28·77 lbs. of tin	14·555 tons

Water Facilities.—Falls.—The Busanga Tin Mine is very advantageously situated as to water privileges for power, sluicing, and all mining purposes, being only a few hundred yards from the Lualaba and Lufupa, two large streams. These rivers form the eastern and southern boundaries of the property.

There has not been sufficient development work done to ascertain if this new-discovered Tin Field is going to be a large and continuous tin producer. But this tin deposit taken in conjunction with the tin deposits of North Nigeria point to the fact that Africa may some day become an important factor in the tin production of the world.

Tin Deposits of Japan.*

This country is also a small producer of tin ; the bulk of it is produced by vein mining, the Taniyama Mine, in the province of Satsuma, being the chief producer, to the extent of about one-half of the total output of lode tin. The ore is contained there in veins running east and west, and traversing a porphyritic rock, probably rhyolite. These veins vary considerably in width and are composed chiefly of quartz and iron pyrites, in which occasionally bunches of tin ore are met with ; the total production not exceeding ten tons.

* Journ. Geo. Society of London.

In the province of Bungo numerous eroded cavities filled with stanniferous gravel containing from 0·3 to 0·5 per cent. of tin are found in crystalline limestone.

A little alluvial tinstone appears to be got irregularly in the province of Mino.

The tin production of Japan used apparently to be more important than it is at present. The average output for the last 10 years is about 12 tons a year.

TIN DEPOSITS OF GREENLAND.

Tin Ore Veins at Arksut, Greenland.—*"The area over which the tin veins occur is 1,500 feet in length by 80 feet in breadth, running E. and W., others N.E. and S.W. The tin occurs disseminated in crystals through the rocks and accompanying the finer grained galena and tantalite. The gangue here is felspar, quartz, sparry iron and fluorspar. The veins are small and belong to the underlying granite, which appears at the surface in veins, and which is probably at not great depth below, since the tin veins penetrate into the overlying gneiss, which dips to the south and under the outcrop of granite loses itself.

"It is highly probable that the cryolite forms a bed between the gneiss and the granite, and partly enclosed in the gneiss. This tin district differs from all others known, being associated with the cryolite, whilst tantalite seems to have taken the place of wolfram." It is of no commercial importance.

TIN DEPOSITS OF FINLAND.

† Tin ore occurs at Pitkäranta on the north shore of Lake Ladoga. Here, too, the geological structure of the country is seen to consist of crystalline sedimentary rocks, traversed by granite. Some of the altered stratified rocks are impregnated in places with tinstone, and are the source of a small production of this metal.

CHINA.

"Tin is known to be produced in the Empire of China, but nothing definite is known as to its localities or mode of occurrence; it is, however, fairly safe to assume," says Professor Henry Louis (in "The Production of Tin" published by the *Mining Journal*) "that it is got from alluvial deposits. In Southern China it is known to occur both in alluvial deposits and disseminated in granite in the neighbourhood of Kotchion, in the district of Moungtsi. This place is the centre of an active tin-producing industry, work being carried out on a large scale; the district is said to produce about 3,000 tons of tin annually. The

* J. W. Taylor, XV. Jour. Geo. Soc.
† "The Production of Tin," Louis.

total tin output of China has been variously guessed at 10,000 to 20,000 tons per annum, though, whatever it be, it is evidently insufficient for the needs of the country, as China imports tin from Siam, the Siamese-Malayan States, the Straits Settlements, and the Netherlands East Indies. It is also quite possible that the neighbouring Shan States, Cochin-China, etc., may send some tin into the Chinese Empire, as the former are said to produce some. It will be remembered that the Chinese have from time immemorial been in the habit of employing bronze largely, this body being an alloy of copper and tin."

* *China's Tin Exports in* 1905.

Mr. Wilkinson, British Consul-General at Mengtzu, reports :—The past year (1905) is the record year for tin. Although owing to the enormous increase in the cost of labour, due to the requirements of the railway, the mine-owners of Kochiu had to reduce their staff by one-half, still the mines and the town had completely recovered from the damage done them in the rebellion of 1903. The result was an export of 74,972 pikuls (89,252 cwts.), valued at £514,034, or 72 per cent. of the total exports. The whole of the tin is shipped to Hong Kong in half slabs measuring 22 inches in length by 9 to 10 inches in breadth and ¾ to 1 inch in thickness. Each half slab (the original "pig" is always cut into two, chiefly for convenience of mule carriage, but also to show the quality) weighs 55 catties (73 lbs.). Its market value in Mengtzu before payment of export duty is, roughly, £6 per pikul of 133 lbs. The trade is entirely in the hands of the Chinese, who would be very jealous of any interference.

Mr. Consul Carlisle, in his report for 1905, says :—The export of tin is an incident of the transit trade. The tin comes from the mines of Ko Tiu, near Mengtse, in Southern Yunnan. These mines are exploited by Chinese who bring the tin into Mengtse, whence it is sent down to Manhao on the Red River and thence through Tonkin to Hong Kong. The total amount of the export during the year was 4,578 tons, valued at £553,915, and of this value only £2,231 refers to Indo-Chinese tin (mostly ore), the bulk of the rest being the Yunnanese product. £526,828 worth of tin came in during the year. This was, of course, the same tin in transit that here appears as an export.

Korea.

Tin is said to be mined in the province of Chulla, at Hainan, Koangchow, and Chyeichow ; it does not appear that the production attains dimensions of any importance.

Siberia.

Tin has long been known to exist in the district of Nerchinsk (Transbaikal), chiefly in the valley of the River Onon, an affluent of the Amur, where deposits of tinstone are known over an extent of above

* "Mining Journal," Sep. 15, 1906.

70 miles. This region is rich in gold placers, and in washing these tinstone was found along with the gold; this discovery led to investigations which resulted in finding the metal in primary deposits in the year 1811. Tin had, however, been worked long before this by the native inhabitants. Here again the country consists of schists, upheaved and traversed by granites, both the stratified and the eruptive rocks being penetrated by a network of veins and veinlets of quartz, carrying, together with the tin ore, the minerals which elsewhere also characterise similar deposits. This region is remote and almost uncivilised, and it appears that work was conducted very crudely and unsystematically, mining in the true sense having scarcely been attempted. It is said that old statistics show that the crude ore raised contained as much as 6½ per cent. of metal. Nevertheless, the industry was never really successful, a fact to which the inaccessibility of the district, no doubt, contributed largely. No work seems to have been done there since 1852, and no statistics as to the amount of tin produced are available. In view of the fact that the Trans-Siberian Railway passes not far from this district, it is now proposed to recommence operations, and if its extent and richness are as considerable as they are reported to be, this may one day become an important centre of tin production.

CHAPTER XIV.

TIN DEPOSITS OF CENTRAL EUROPE, SPAIN, PORTUGAL, FRANCE, ITALY, SCOTLAND, IRELAND, MEXICO, UNITED STATES OF AMERICA, AND ALASKA.

TIN DEPOSITS OF CENTRAL EUROPE.

TIN MINING in Central Europe was an important industry for many years. Tin was first worked in the Altenberg district in 1459; the output was not over 300 tons for many years, and this has gradually dwindled away to comparatively nothing. The geological features are interesting. The rocks round Altenberg which contain the large tin ore deposits are mostly a greyish coloured porphyry, gradually merging into a form of greisen; a large mass consisting of chiefly quartz and mica over 1,200 feet in length and 800 in width contained the tin ore. The ore is disseminated through the mass in exceedingly small particles; it is locally known as zwitter, it has a dark grey or greenish colour, and sometimes almost black. It is of a remarkably fine texture, and is composed essentially of quartz with chlorite or lithia-mica, specular iron, wolfram, mispickel and cassiterite; the quartz, which is in an amorphous condition, is plainly distinguishable. This rock differs from an ordinary greisen, as it contains chlorite and specular iron. Over the whole body small fissures about 8 inches in width occur, and this formation is now generally termed a stockwork. The rock mass surrounding this formation is a porphyritic granite; it is finely grained, and carries a quantity of pink felspar.

The stanniferous strings or veins of quartz that occur are merely extensions of those traversing the formation on either side. Van Cotta, who has written extensively on the geology of this district, considers that the "zwitter" is merely an altered form of what was once a granite, similar to that at present next it, which became impregnated with solutions of silica and tin in combination with other elements.

* The stanniferous deposits of Gottesberg and Brunndöbra, near Klingenthal. A few of the widespread ancient workings, abandoned for many generations, have been lately made accessible again, and thus a scientific investigation of the deposits has become possible. They are evidently associated with the contact-metamorphic zone which marks the junction of the intrusive, coarsely crystalline tourmaline-granites with the older phyllites, quartz-schists and hornblende-schists.

In the Gottesberg district, the ore-occurrences consist partly of small crystals of cassiterite impregnating grey quartz, and partly of

* "Zur Kenntniss erzgebirgischer Zinnerzlagerstätten. By O. Mann. Abhandlunger der naturwissenschaftlichen Gesellschaft 'Isis' in Dresden, 1904, part ii, pages 61–73."

tin-ore in a microscopically fine state of division, associated with fairly large grains and nodules of pyrites and arsenical pyrites. In following up a deposit of the latter kind, it is found that the sulphidic ores gradually assume the predominance, to the ultimately complete exclusion of the tinstone. Most of the minerals that one is accustomed to associate with stanniferous deposits, such as topaz, fluorspar, molybdenite, etc., are here conspicuous by their absence. Veins of chert, bearing red hæmatite, are associated with the tinstone-bearing veins, or are seen to cut across them.

In the Brunndöbra district especially do the veins occur in the contact-metamorphosed slates: the pitch is generally steep, and the strike all but universally northerly or north-westerly. The main mass of the veins consists of quartz and tourmaline, the latter exhibiting certain crystallographic characters which are reminiscent of the analogous mineral from the Mount-Bischoff tin-ore deposits in Tasmania. The tinstone seems to be concentrated by preference in those parts of the veins which are richest in tourmaline. Under the microscope the cassiterite-crystals are remarkable for their concentric zonal structure, as many as ten light and dark bands alternating in some cases. Needles of tourmaline are seen to pierce them, and in some instances the cassiterite presents the appearance of having been "gutted," so to say, and then "restuffed" with tourmaline; but in no case is a cassiterite-crystal embedded or included in the tourmaline. Irregular masses of red hæmatite are of common occurrence in the gangue. The hæmatite-veins proper, of later date than the cassiterite-veins, repeatedly cut across the latter. The stanniferous veins, being only from 4 to 12 inches thick, would hardly have given rise to mining operations of any considerable extent, had it not been for the "impregnation-zone" extending on either side for about 20 inches into the metamorphosed country-rock. In some cases, the area of impregnation was immensely extended. It is often very difficult to determine exactly where the vein ends and the country-rock begins. The stanniferous veins are supposed to have been formed at a time when the granite-intrusion had already begun to solidify superficially, and simultaneously with the silicification of the neighbouring rocks. They are not, as at Mount-Bischoff in Tasmania, genetically associated with the advent of the topaz (which was a later comer than the cassiterite at Brunndöbra); while on the other hand, those Tasmanian tin-ores do not actually occur in tourmaline-rock as do these Saxon ores. In outward appearance, the close resemblance between the Mount-Bischoff and the Erzgebirge deposits is very remarkable.

Arthur G. Charleton, in his book of ' Tin Mining " (page 9), gives the following account of mining operations at Altenberg:—

"The method in operation in these mines is the so-called 'Stockwerks-bau,' but it can only be employed in those parts of the deposit where the zwitter is impregnated with cassiterite in sufficient quantity, or a network of small veins bunch together; for it should be explained that the mere presence of cassiterite does not alone constitute a stockwork—*Germ.* Stockwerk—as the term is applied only to those centres of enrichment where the rock, though comparatively poor, appears to

be rich enough to be mined at a profit. Stockwerks-bau would indeed never be followed unless considerable portions of the rock were barren, and the value of the pay-rock comparatively so small and variable that large quantities must be got out to make it pay; and, from circumstances outside of the miner's control, no regular plan of working can be maintained underground.

"In mining by this system at the present time, drifts are driven from the Römer shaft at every 63 feet in depth with the aid of explosives; and as soon as the deposit is reached, cross-cuts are started from the main levels in safe ground towards supposed points of enrichment, where the ore is worked out generally by over-hand stoping in floors one underneath the other, each consisting of several approximately circular chambers, which are often 40 to 50 feet in diameter, and 35 to 45 feet high.

"Having in the first instance made one of these excavations, the next step is to drive one or more galleries in any desired direction, just sufficiently long to leave a safety pillar of comparatively poor rock, usually 15 to 25 feet in diameter, between the last chamber and the nearest point where ore can be found that can be worked in a similar manner; and thus a series of chambers is formed, irregularly placed with regard to one another, on the same storey of massive pillars of 'country rock.'"

Mining in the Zinnwald.

In the Zinnwald District tin ore occurs in a granite rock sometimes called a greisen; this rock contains only a small proportion of felspar, the whole mass is stanniferous in parts, but the richer deposits occur in concentric zones, about 10 inches thick.

The following section is taken from the "Vereinigt Zwitterfeld," by A. G. Charleton, and given in his work on "Tin Mining" (page 49).

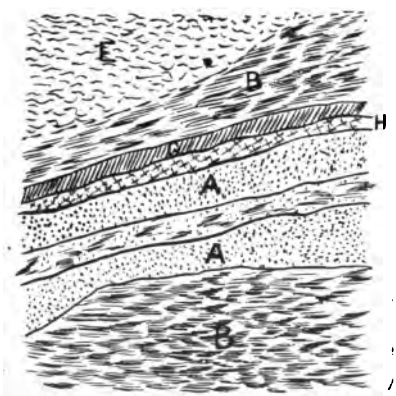

Fig. 29.

It shows admirably the general ribbon-structure of "the beds," consisting, as may be seen, of streaks of "pay" (AA), alternating

with parallel layers of barren vein-matter, or country rock; whilst underneath "the greisen" (B), that passes into granite (E) and forms the roof, there is a soft white decomposed layer of kaolin (G), separated from the filling of the vein by thick lenticular tufts of green mica (chlorite) (H) interbedded with very large and perfect crystals of wolfram and quartz, the latter mineral frequently occurring "capped."

The following account is taken from the "Genesis of Ore Deposits," page 54:—

"The tin deposits of Altenberg and Zinnwald in Saxony have lately been investigated by K. Dalmer. The cassiterite deposits of Altenberg consist, as is well known, of a number of ore-fissures which sometimes carry a notable amount of quartz, mica, and topaz, as well as cassiterite. Over a considerable area traversed by these veinlets appears a greisen locally known as zwitter, which Mr. Dalmer shows to have resulted unquestionably from the metasomatic alteration of the granite. This process consists of a replacement of felspar, principally orthoclase, by topaz, containing lithium and fluorine.

"The beginning of the process is often visible, small strings of aggregates of mica and topaz pervading the felspar. These strings repeatedly cross each other, and by extension of the mineral individuals complete replacement is attained. The greisen consists of: Quartz, 50·28; topaz, 12·14; mica, 36·18; and cassiterite, 6·43; total, 99·65 per cent."

Tin Deposits of Spain.

Although tin has been mined for in Spain more or less since the time of the Phœnicians, it has never been an important factor in the tin production of the world. Tin occurs both in the alluvial wash and in lodes. Mr. James Mactearn, in a report on some alluvial ground known as the Arnoyaseco alluvial deposit, describes the tin drift as being more or less sandy in character containing a little clay, having an average value of about 2·50 kilos of black tin per cubic metre. The country rock here consists mainly of schists and slates broken by masses of intruding granite; quartz veins are found traversing both of these rocks in which occur irregular bunches of tin ore.

The rate of wages in this district is given as follows:—

	s	d.		s.	d.	
Miners - - - - -	1	3	to	1	8	per day.
Women and boys - - -	0	$7\frac{1}{2}$	to	1	0	"
Carpenters - - - - -	2	1	to	2	6	"
Smiths (providing tools) - -				4	0	"
Do. (without ") - -				2	6	"
Bullock cart and driver - -				5	0	"

In the provinces of Orense and Ponteredra, the tin deposits occur over an area of about 12 square miles, and a number of lodes have been

intermittently worked here for long periods. The veins carrying the cassiterite are generally small, averaging about 8 inches, and traverse the mica schists and hornblendic rocks in which they occur. The veinstone is mainly quartz, mica being present in small quantities, the lode also carries wolfram and iron pyrites in varying quantities, the tin ore occurs in irregular masses. * In the province of Salamanca there are, traversing the older slates, quartz lodes which contain tin ore, and in 1875 tin mines of that region afforded employment to about 70 workmen.† Near Carthagena tin ore occurs in lenticular deposits in Permian slate.‡ Tin ore has also been found in the province of Almeria.§

TIN DEPOSITS OF PORTUGAL.

Tin deposits occur in the provinces of Beiro, Minto, and Tras-os-Montes. Alluvial tin ore is found in the drift, and the working of these gravels in a small way has been carried on from the time of the Romans.

The tin occurs in the stockwork formations in the granite, but the tin ore is irregularly disseminated. Tin is also found in small veins traversing the slates, and in the province of Tras-os-Montes some veins were sunk on to a depth of 150 feet, but the ore was too poor and irregular to pay, and the work consequently abandoned.

At the present moment the value of the tin output per annum is under £500 a year in value.

TIN DEPOSITS OF FRANCE.

Tin has been mined at Pitriac and Lakilleder in Brittany, where the geological conditions resemble those of Cornwall—that is to say, it is a district composed chiefly of clay slates corresponding to the killas of Cornwall. These have been broken through by granite upheavals—the whole are traversed with porphyry dykes. Serpentine also occurs in irregular masses.

|| The tin ore is found in small quartz veins, and disseminated in the rocks themselves at the junction of the eruptive masses and the altered sedimentary formations. Nothing answering to the strong masterly lodes of Cornwall has, however, yet been discovered, and all attempts at mining tin ore on a commercial scale have proved to be disastrous failures.

At the Moulin de la Villeder, near the rock Saint-André, a vein of stanniferous quartz is enclosed in granite.

* Phillips and Louis, "A Treatise on Ore Deposits," p. 504.
† Massaret, "Ann. Soc. Geol. Belg.," 1876, II., p. 58.
‡ M. Garcia, "Boletin de la Comision del Mapa Geologico de España," III., 1876, p. 2.
§ "Revista Minera," 1821, p. 148.
|| Louis, "The Production of Tin."

At Pyriac the clay slate is in contact with the granite, and at their point of junction there are some small veins of quartz in which the tin ore occurs in irregular bunches.

However, as a tin producer, France is an unimportant factor in the world's production.

Tin Deposits of Italy.

Although economically unimportant, these deposits possess considerable interest. Tin was first discovered in 1875, near Campaglia Marittima, a small town situated about four miles from the Tuscan coast and about 35 miles south-east of Leghorn. It was while looking for iron ore in some ancient excavations that the discovery of the existence of tin ore was first made. The cassiterite here is associated with calcite and ferric oxide. The ancient mine is known as the Cento Camerelle, and has been extensively worked for hæmatite. The tin lode was found about 50 feet west of the ancient workings. The general strike of the lode was east and west. The cassiterite was in places replaced by hæmatite. In 1877 about 20 tons of tin ore was obtained, but since then nothing of importance has been done, and the latest mineral returns of Italy show that there is no tin ore produced at present.

Tin Deposits of Scotland.

The following is an extract by Dr. Flett and Mr. C. T. Clough taken from "The Memoirs of the Geological Survey," 1903 :—

"In the foliated granite gneiss of Carn Chuinneag, Ross-shire, magnetite is found in streaks and veins along two bands which can be traced for a distance of 100 and 250 yards respectively, and have a breadth of 10 and 15 yards. Probably there are other localities in which magnetite occurs, as loose blocks of it, apparently weathered out of the adjacent rock, are found scattered over the hillside. It is believed to be a basic segregation, or perhaps a series of veins in the original igneous mass, but both have been much altered by shearing, and their exact relationships are somewhat obscure. It is possible that the magnetite veins really belong to the sediments of the Moine series, now converted into granulitic gneisses and mica schists. In these there are bands of heavy minerals, which indicate the original bedding, but one specimen of iron-ore from the Moine gneisses was tested in the laboratory and proved to consist of hæmatite (not magnetite) and to contain no cassiterite.

"A specimen of the magnetite sent in by Mr. Clough shows that there is a varying percentage of cassiterite in the rock. Microscopic sections prove that some parts of the specimen contain very little tin dioxide, while in others it is abundant. In addition to magnetite and cassiterite, quartz, orthoclase and plagioclase felspars, muscovite, biotite, and rutile occur, and these are so distributed as to give the mass a foliated structure.

Analysis of Magnetite by Dr. Pollard.

SiO_2	7·97
Al_2O_3	·98
Fe_2O_3	60·69
FeO	25·94
MnO	·16
CaO	·59
MgO	·26
SnO_2	3·22
H_2O at 105° C.	·06
H_2O above 105° C.	·43
Total	100·30

"Alkalies not estimated. No other elements excepting a trace of Titanium and a doubtful trace of Tungsten were found.

"Magnetite occurs disseminated through the granite in small patches and isolated crystals of small size, enclosed in the other minerals, but an examination of the microscopic sections in which it was thought likely that cassiterite might occur has failed to indicate its presence.

"Apart altogether from the possible economic importance of this discovery, about which it is premature to speak, there are certain other points of interest about it to which reference may be made. It is the first recorded occurrence of tinstone in Scotland, as though this mineral is abundant in Cornwall, and has also been found in Ireland, it has not been hitherto proved to accompany any of the numerous granitic intrusions in the Scottish Highlands and Southern Uplands. Moreover, if the preliminary hypothesis indicated by the facts as at present known be correct, viz.—that the magnetite and cassiterite are early basic segregations from the granitic magma, the mode of occurrence is of great interest, and is perhaps unique. Tinstone is mostly found either in sands and gravels derived from the wear and tear of the lodes, or in veins and impregnations accompanied by quartz, tourmaline, and chlorite. If such veins had once been present in the Carn Chuinneag granite, and had been subsequently torn out and crushed during the earth movements which converted the granite into a gneiss, they could not have produced the tinstone and magnetite nodules, for quartz is comparatively rare, and tourmaline does not occur. There is evidently something unusual about these deposits."

Occurrence of Tin in Ireland.*

Tinstone has been found at Ballinasilloga, and on the high ground at Ballinavally, but it is of no commercial importance.

The Tin Deposits of Mexico.

Uncertain when tin was first discovered in Mexico, but it is certain the mines were exploited by the Spaniards at an early date. The first

* Phillips and Louis, "Treatise of Ore Deposits," p. 312.

exact reference was made in Humboldt's "Essai Politique sur la Royaume de la Nouvelle Espagne." *

The export of tin from Mexico in 1903 was 58·5 quintals, equivalent to 5,934¼ lbs.

Tin is widely diffused, but the chief centres of mining are Cacaria and Potrillos, in Durango, and Teocaltiche, in Jalisco.

Potrillos, which is the name of one of the outlying ranches of the great ranch of Guatimape, is situated in the Sierra de San Francisco, a span of the Sierra Madre, about 100 miles north of the city of Durango, and 25 miles from Coneto. All transport except over the main road to Coneto has to be done by pack animals, horses, mules, and burros.

The general altitude of the valleys of Potrillos is probably 6,500 to 7,000 feet, the crests of the mountains being 1,500 to 2,500 feet higher.

The rainfall is very heavy from July to October. The region is sparsely timbered with pine, scrub, oak, and madrona.

The first can be used for mining timber, and the last two for firewood. The black tin produced was smelted in Potrillos region.

The geology of the Potrillos district is simple. The prevailing rock is rhyolite and rhyolite-tuff, chiefly the latter. This rock covers vast areas in the northern and north central parts of Mexico.† Beyond the limits of the sheet of young igneous rocks a grey, finely crystalline granite is exposed, and is probably the underlying rock. Cassiterite occurs in the rhyolite-tuff along the fault planes in aggregations of nuggets (called guijilos by the native miners), and occasionally in bands of crystalline mineral, replacing the country rock between two sheeting planes. With the former the cassiterite is often very finely disseminated, so that it will not average 1 per cent. of tin. The ore mined is generally worth 3 to 10 per cent., and is broken from faces 3 to 4 feet wide.

These ore bodies are exceedingly ill-defined, passing into barren country rock by insensible gradations.

‡ In the State of Durango the country rock is generally rhyolite, rhyolite-tuffs, and quartz porphyries. Some of the mineral associations common to other deposits are also to be noted here, more especially the presence of topaz, and of other minerals containing fluorine. On the other hand, wolfram is rare, and some of the Durango tin ores present the very curious phenomenon of being intimately associated with antimonial and arsenical compounds. Stream tin has been worked, but the quantity is limited on account of the physical peculiarities of the country, its steeply-precipitous but narrow valleys, and the small rainfall. It seems probable that the greater part of the small amount of tin-bearing alluvium that could accumulate under these conditions has already been exhausted, and a certain amount of vein mining has been done, generally in a desultory manner ; but little tin in the aggregate

* Paris, 1827, Tome III., 308, and Tome IV., 76.
† These rocks were identified by Prof. J. F. Kemp.
‡ Louis, "The Production of Tin."

has yet been obtained, and apparently there has been no systematic prospecting.

The following account of the Sain Alto Tin Deposits, by J. Nelson Nerius, was taken from the *Engineering and Mining Journal* of 20 June, 1903 :—

"The mountains south of Sombrerete and west of Sain Alto, in the State of Zacatecas, Mexico, have been frequently mentioned in connection with deposits of tin ore. The region yields a small amount of this metal annually, but it is much less than is commonly supposed.

"The mountains are all of rhyolite, which has been forced up through the vast thickness of thin-bedded shale and limestone, generally accredited to the Cretaceous age. The rhyolite is quite uniformly rifted in a general north-westerly direction, and the fracture planes thus produced give access to the circulation of water which occasionally causes considerable decomposition of the rhyolite along the fractures and the impregnation of oxides of iron, manganese, and tin. Small chambers have been found along these seams from which a few tons of good tin ore have been extracted. No regularity in the occurrence of such deposits has been determined, and none can logically be expected to occur. In these seams the tin oxide is badly adulterated with iron and manganese oxides.

"In many places bands of the rhyolite occur carrying amygdaloids of chalcedony. Such outcrops are frequently mistaken for vein indications. Along with this chalcedony occasional nodules of cassiterite are to be found, which, after weathering out of the rock, becomes concentrated in the deep ravines. This is the source of most of the tin produced in this district. The native ranchmen, during and after the rainy season, search the ravines and recover the ore. Nearly all of it is picked by hand from crevices in the rocks over which the streams flow. The natives pay little attention to the small banks of gravel, although, by panning, these yield a very small amount of fine ore. The sides of the ravines are so abrupt that no gravel deposits can accumulate along them. Where the streams leave the mountains and flow out upon the surrounding plains, large areas of sand and gravel have accumulated, and it is possible that these deposits may contain valuable amounts of tin ore. At present the ranchmen recover all the available ore from the stream beds, and the seams in the rhyolite are not sufficiently promising to warrant development, although several claims have been *denounced* (taken up) upon the neighbouring mountains.

"Amygdaloidal deposits of chalcedony occur in other parts of Mexico in rhyolitic formations along with cassiterite ; apparently they can be regarded as an index when searching for that ore.

"The following statistics were compiled from the bills of sale of metallic tin purchased in Sain Alto during three years, which documents were courteously loaned by the purchasing agent. The grade of ore is taken at 40 per cent., because considerable of the ore smelted in those years came from some of the old mines. The iron and manganese in the ore as mined reduced the grade and made the charge refractory in the furnace.

METALLIC TIN PURCHASED IN SAIN ALTO.

Year.	Weight of Metallic Tin-kilos.	Price per kilo. Mexican money.	Total Value.	Grade of Ore (estimated).	Weight of Ore in kilos
1900 - -	201·60	$ ·925	$186·48	40 per cent.	504·00
1901 - -	441·00	1·169	515·53	40 per cent.	1,102·02
1902 - -	145·70	1·140	166·10	40 per cent.	364·25
	788·30		$868·11		1,970·27

"As nearly as could be ascertained, the sales in Sain Alto represent about one-third of the production for the years mentioned. The larger producers sell their metal at higher figures to actual consumers in Zacatecas and Mexico City. Therefore the production of tin ore from this region was about as follows, stated in short tons: 1900, 1·5 tons; 1901, 3·5 tons; 1902, 1 ton. No figures are available for the current year, but a few tons will be smelted after the rainy season."

It seems probable that, though tin ore occurs very widely distributed throughout Mexico, there are few, if any, individual rich or important deposits. No statistics of production are obtainable from Mexico; statistics of exports and imports show figures fluctuating considerably, but always small, whilst the imports appear always to exceed the exports, so that the country is not quite self-supplying. As, however, imports and exports together never seem to reach 100 tons a year, the matter is quite unimportant, and it will be best to simply look upon Mexico as merely a potential small contributor, bnt not an actual contributor, to the world's supply of tin.

TIN DEPOSITS OF THE UNITED STATES OF AMERICA.

The total amount of metallic tin produced from ore mined in the United States has not exceeded 200 tons, though small amounts have been found in no less than seventeen States and Territories; Alabama, Alaska, California, Colorado, Connecticut. Georgia, Idaho, Maine, Massachusetts, Missouri, Montana, New Hampshire, North Carolina, South Dakota, Texas, Virginia, Wyoming.

In Alabama, cassiterite occurs in quartz veins in graphite schists * near granite, and as disseminated grains in gneiss.

In California,† small amounts of float cassiterite have been found in the gold placers at a number of widely separated localities. The ore

* Phillips, Wm. B., "Geol. Survey of Alabama Bull.," No. 3, 1892.

† "Sixth Ann. Rep. California State Min. Bureau," Sacramento, 1886, "Eleventh Ann. Rep. California State Min. Bureau," Sacramento, 1893. Fairbanks, Harold W., "Tin Deposits at Temescal," *Am. Jour. Sci.*, 4th Ser., Vol. IV., 1897: pp. 39–42. Rolker, C. M., "Production of Tin in Various Parts of the World. Sixteenth Ann. Rep. U.S. Geol. Survey," Pt. III., 895, p. 536.

is found in places at the Temescal mine, five miles south east of Riverside. At this place there is an area of hornblendic biotite-granite over two miles in diameter, which is cut near its borders by dykes of highly quartzose and felspathic fine-grained granite. The ore occurs in veinlets of tourmaline and quartz aggregates which run north-east and south-west through the granite. A great body of such vein matter, covering an area 300 by 250 feet, and 25 to 30 feet high, crops out in the Cajalco Hill. What is known as the Cajalco vein courses north-east from this outcrop, and the workings extend for 1,000 feet along it. The vein is sinuous, and varies from a minimum of a clay seam to a maximum of 8 feet. There is always a clay gouge on one and often on both walls. Two hundred and ninety-one and fourteen one-hundredths pounds of metallic tin were produced from ore mined at Temescal previous to 1892, when the mines were abandoned.

In the Carolinas a tin belt * extends in a north-east-south-west direction for about 31 miles, and lies partly in North Carolina and partly in South Carolina. Tin ore is not evenly distributed through this distance, though the tin-bearing formation, which consists of crystalline schists or gneisses containing pegmatitic dykes, is continuous. The rocks of the tin belt are very much decomposed, and the pegmatite dykes are very thoroughly kaolinized. The tin ore has been found loose in the soil, in the gravels, in boulders of quartz and mica, and occasionally in the pegmatite dykes. The most promising deposit on the belt is at the Ross mine, near Gaffney, S. C., from which 34,471 pounds of the ore were shipped in 1903 ; 75,000 pounds shipped in 1904 assaying 66 per cent. metallic tin.

In Colorado tin ore has been reported near Golden, but little is known of its occurrence.

In Connecticut tin ore has been found at Haddam, but only as a mineralogical curiosity.

In Georgia tin ore has been reported from Lumpkin County, as occurring in granite and chlorite schists, with minute quantities from the gold washings.

In Idaho a few specimens of stream tin have been found on Jordan Creek, in the south-western part of the State, and in the Cœur d'Alene district.

In Maine † a cassiterite occurs at Winslow in small veins, which traverse impure limestone, with purple fluorite, mica, quartz, and mispickel. These veins have been prospected to a depth of 100 feet, but have yielded no tin in commercial quantities. Similar occurrences are reported at Paris and Hebron.

In Massachusetts a few crystals of cassiterite have been found with albite and tourmaline at Goshen and Chesterfield.

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* This note is furnished by Joseph Hyde Pratt in advance of Economic Paper, No. 8, of the North Carolina Geological Survey on "Carolina Tin Deposits."

† Jackson, C. T., "On the Discovery of a New Locality for Tin Ore in Winslow Me. : Proceedings, Boston Soc. Nat. Hist.," Vol. XII., 1869, p. 267. Hunt, T. S., "Remarks on the Occurrence of Tin Ore at Winslow, Me. : Trans., Am. Inst. Min. Eng.," Vol. I., 1873, p. 373.

In Missouri * a small amount of cassiterite has been found replacing sphene in granite.

In Montana,† stream tin has been found in Prickly Pear, French Bar, and Ten Mile Creeks, in the " Basin," in Basin Gulch and in Peterson Creek. Light-brown, rounded pebbles of wood tin associated with topaz crystals have been found at one locality.

In New Hampshire cassiterite was found at Lynn and Jackson, in 1840, by Dr. Jackson. It occurs with arsenical and copper pyrites, fluorspar, and phosphate of iron in small quartz veins, and mica, slate, and granite near a trap dyke.

In South Dakota,‡ the Black Hills contain noteworthy deposits of tin ore, which, however, have not yet proved commercially productive. They occur in an area of coarse-grained granite in the central part of the hills. The Etta mine deposit, the only one that has produced any considerable quantity of tin, is a lenticular body of pegmatitic granite, which consists of quartz, felspar, (albite) lepidolite, and spodumene in individuals of great size, up to eight or nine feet in dimensions. Cassiterite occurs in association with lithia, mica, and is accompanied by columbite and tantalite, with which it is apt to be confused. The mine was sold to an English Company, which erected a 250 stamp mill, but the ore did not prove profitable to work, and after the first run, which produced 9,385 pounds of tin, the work was closed.

§ Although there has been no appreciable development of the Harney Peak properties, the Tinton Tin Company, controlled by Chicago interests, has been working during the last two years on its claims situated in what is known as the Nigger Hill and Bear Gulch districts, west of Deadwood and Lead, S. Dak., and 75 miles northwest of Harney Peak. This new district is partly in Lawrence County, S. Dak., and partly in Crook County, Wyo., being on the border line of the two States. The Tinton Tin Company have been working a small concentrating plant, but, owing to the lack of proper smelting facilities in the United States, they have shipped to European ports for treatment a carload of concentrates said to contain an average of 62·5 per cent. of metallic tin. One parcel of the Company's property, 140 by 50 feet, and another 90 by 6 feet, yielded an average mill return of 1·16 per cent. of metallic tin, which was 0·16 per cent. greater than the assays of hand samples made in the laboratory. The quantity of ore so far treated has averaged 1 per cent. of metallic tin, and the concentrates therefrom have ranged from 62·5 to 65 per cent. of metallic tin.

In Texas,‖ tin has been discovered in quartz veins, occurring in greisen granite in the Franklin Mountains near El Paso, and one small

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* Raymond, R. W., " Trans., Am. Inst. Min. Eng.," Vol. I., 1873, p. 374.

† Ibid.

‡ The writer is indebted to Mr. S. F. Emmons for the note on tin in South Dakota.

§ " Board Trade Jour." 1905.

‖ Dumble, E. T., " Second Ann. Rep. Texas Geol. Survey," 1890, pp. 595, 690, 713

crystal has been found at another locality. At El Paso, * wolframite occurs with the ores, and felspar is replaced by cassiterite.

In Virginia,† good tin prospects have been found on the headwaters of Irish Creek, Rockbridge County, in quartz lenses and stringers in granite, which itself is intrusive in metamorphic schists. Associated minerals are wolframite, mispickel, iron pyrites, quartz, and beryl, with small amounts of siderite, limonite, chlorite, muscovite, damourite, and fluorspar.

In Wyoming, at‡ Nigger Hill, in the north-western portion of the Black Hills, cassiterite has been found in a granitic area that is similar in geological association to that at the Etta mine.

Tin Deposits of the York regions of Alaska. §

The steady advance in the price of tin within the past few years, coupled with the enormous and increasing consumption of this metal in the United States (the American Tin Plate Company alone already using over $7,000,000 worth per annum), has naturally greatly stimulated the search for tin ores in the United States, with a view to rendering this country less dependent on foreign sources of supply.

Probably the most extensive development work has been carried on in North Carolina and South Carolina. One mine in South Carolina has already produced over 60 tons of tin concentrates. Considerable stream tin has for many years past been found in the ravines and streams of South Carolina, but during the past year quite extensive mining has been conducted in the immense pegmatite dykes that traverse the granite and slate areas of the Carolinas.

Quite recently veins of tin ore in granite have been discovered in the State of Texas near El Paso. The tin is said to be of high quality, and the prospects look extremely good for the amount of development done.

The old Temiscal Tin Mine near San Diego, in the southern end of California, is now being operated under lease, and the lessees report a saving of 2 per cent. black tin from the tailings of the former works. The proprietary (English) company formerly did extensive development work on a capital of $100,000, with the inevitable result that the company became involved and the works were closed down. Tin exists in the veins, which are quite numerous, but it is not yet satisfactorily settled whether the tin occurs in quantities that would pay even with the most modern methods and machinery and the best management.

The occurrence of tin-bearing lodes in the bed-rocks has been verified by the Geological Survey at points known as Lost River and Cape

* Rolker, C. M., "Production of Tin in Various Parts of the World: Sixteenth Ann. Rep. U.S. Geol. Survey," Pt. III., 1895, pp. 523-525.

† Rolker, C. M., op. cit.

‡ Ibid.

§ Arthur J. Collier, "Gov. Geological Survey of U.S. America."

Mountain. The occurrence of alluvial tin (placer deposits) has been confirmed on Anikovik, Buhner Creek, a tributary of the Anikovik, and on Buck Creek, a tributary of Grouse Creek, which flows through Mint River into the Lopp Lagoon.

Tin ore has also been reported from a great many other localities which have not been thoroughly examined by geologists. The tin deposits, as far as known, do not follow any definite system, and are confined to no particular belt or zone.

The succession of rocks as far as determined is as follows:—The oldest sediments are limestones which are white and usually crystalline. They are often beautifully banded and occasionally have intercalated bands of mica-schist. This bed of limestone is near the coast, and is about half a mile in width. Cape Mountain is made up of a mass of granite which has intruded into limestones. Along the crest of the mountain, pillars and pinnacles of granitic rock are common, and are due to the existence of a double system of jointing. The granite, except for this jointing, is entirely massive and usually coarsely crystalline. Near the margin of the mass it contains large crystals of felspar. To the north of the limestone a belt of slates and siliceous schists about five miles in width has been mapped, which are regarded as overlying the limestones conformably. The evidence of conformity is that the strikes have a general parallelism to those limestones and the dips are variable, suggesting about the same amount of folding as has taken place in the limestone belt. These slates, and especially the schists, are usually traversed by numerous joint plains by which they are split up into rhombohedral forms. These beds are occasionally calcareous, but more often graphitic. With the slates, series of greenstones of varying descriptions are frequently found. These greenstones are usually massive as though they had suffered some jointing like that found in the slates. They are apparently largely of a diabase character. To the north-east of this slate series, and overlying it, there was found a belt of earthy limestone with some slates. These rocks seem to be less altered than the slate series, though they are apparently conformable. Only a few exposures of this rock were studied, however, and no details can be given.

The unconsolidated deposits of this region can be classified as (1) river and stream gravels, and (2) bench gravels. The first include the gravels and sands of the flood plains of the streams and rivers. The bench gravels are marine deposits which were laid down during the epochs of submergency.

The known occurrences of tin ore will be described under the headings "Lost River," "Cape Mountain," "Buck Creek," "Buhner Creek," and "Anikovik River."

* Lost River.—Lode tin deposits have been found four and five miles from the coast on Lost River. Its two tributaries, Tin Creek and Cassiterite Creek, enter from the east about three miles and four miles

* "U.S.A. Geological Survey," Series A., Economic Geology, 33, 1903.

respectively from its mouth, and tin ore has been found on both of these Creeks.

A white porphyritic dyke, cutting the limestone four and five miles from the coast, forms the present point of interest to the tin miner. This dyke, which is about 100 feet wide, has been traced from Tin Creek on the east, to Cassiterite Creek on the west, a distance of about a mile. Tin ore has been found on the outcroppings of this dyke, and distributed along the surface of its course. Some of the ore is highly siliceous, and carries small crystals of black cassiterite, whilst other specimens of the ore are clearly of granitic origin. The cassiterite in this ore occurs as disseminated crystals of varying size, the accompanying minerals being tourmaline, pyrite, galena and garnet.

A specimen of placer tin ore (alluvial) obtained near the outcroppings of this dyke consists mainly of cassiterite, wolframite and garnet being present. The evidence in regard to this deposit shows it is in part at least essentially an altered granite porphyry (greisen) having crystals of cassiterite disseminated through it. The greisen forms a dyke which has been followed from Cassiterite Creek to Tin Creek, a distance of 6,000 feet. Some crosscuts have been made near Cassiterite Creek on this dyke, and the width given approximately at 100 feet; but it has not been possible to ascertain its true value up to the present.

Cape Mountain.—The Cape Mountain Tin Deposit occurs in a high peak which marks the western point in America.

The ore obtained here differs in appearance from that on the "Lost River." Large pieces of pure cassiterite, several pounds in weight. have been found, and these specimens show no outward signs of crystallization.

The tin ore was discovered in Cape Mountain in July, 1902, and extensive developments were planned for 1903, but owing to a breakdown in machinery these have been delayed.

Buck Creek.—Buck Creek is the scene of the first attempts of tin mining in Alaska. This Settlement is 20 miles north-east of York, and 4 miles from Lopp Lagoon, an inlet from the Arctic Ocean. Buck Creek is a small stream, five miles in length, running into this Lagoon.

Mr. Edgar Richard, in the *Engineering and Mining Journal* for January 3rd, 1903, reports that the source of the cassiterite can be readily found in the slates of the Potato Mountain range in countless small veins or vugs, the denudation of the slates leaving the cassiterite to be concentrated into the alluvial deposits.

The gravel deposits in the bed of Buck Creek average from 100 to 150 feet wide, except in a few greenstone boulders found in the mouth of Satter Creek. They consist of slate and quartz together with other minerals derived from the country rock, such as hæmatite, limonite, magnetite, ilminite, pyrite, cassiterite, and a small amount of gold. Cassiterite in the form of stream tin is distributed from the mouth of the creek to within a mile of its head, the ore varying greatly in size.

The ore from the workings near the mouth of Buck Creek is generally well rounded, while that obtained near the creek is sharp and

angular. The ore varies in colour from black to light resin or amber. A number of specimens were obtained that showed pieces of quartz and slates from the bed-rock still attached to them ; and some small pieces of cassiterite have been found enclosed between fragments of slate, showing that they were broken out of small veins in the slate. Pannings made at the head of Buck Creek gave an average value of 8 lbs. of 60 per cent. ore to the cubic yard.

On the evidence of prospectors it seems that this uniform distribution through the gravel prevails generally along the creek.

The gravel deposits on Grouse Creek, below the mouth of Buck Creek, seem worthy of attention. They are more extensive than those on the Buck Creek, but the amount of tin ore is reported to be very small.

Outside the creek bed there is a covering of moss and débris above the gravel, and no ore is known to be found on the hill-side. The thickness of the tin-bearing gravel varies from a few inches to five feet. Several companies are actively engaged in exploring claims on the Buck Creek, but the methods of mining and sluicing the stream tin are still somewhat primitive.

The first discoveries of tin ore in the York region were made on the Anikovik River and Buhner Creek, a tributary of this river. In the lower part of the Anikovik River, there are rather extensive gravel deposits; the bed-rock consists for the most part of slates.

Buhner Creek has a length of about a mile, and flows in a sort of V-shape gullet, cut in the slates. On this creek, the stream tin is found concentrated on the bed-rock with other heavy minerals. The sample of the concentrates from the sluice box yielded the following minerals:—Cassiterite, magnetite, ilminite, liminite, pyrite, phlorite, garnet and gold. The determination by percentage of weight is as follows :—90 per cent. of tinstone ; 5 per cent. magnetite ; and other minerals 5 per cent. ; but these workings have now been abandoned, as the minerals were not found in sufficient quantities to pay, but might be made to yield fair returns if economically worked on an extensive scale by hydraulic methods.

Discoveries of tin-bearing lodes have been reported by prospectors from many other localities in Steward Peninsula, some of which deserve notice, since geologic conditions are known to be promising. These localities are Brooks Mountains, near the head of Lost River, four miles north of Lost River Tin Deposits ; the hills east of Don River ; Ears Mountain, about 50 miles north of Port Clarence ; Hot Springs, about 70 miles north-east of Port Clarence ; Asses Ears, about 20 miles south of Kotzebue Sound ; and the Diomede Islands in Behring Strait, about 30 miles off Cape Prince of Wales Island. The above facts show cassiterite to be regularly distributed through an area of 450 square miles, embracing the western end of Steward Peninsula.

The tin ore is almost all cassiterite, though a little stannite has been found at one locality. The matrix of the tin ore is in deposits of at least two essentially different types. In the one it is in quartz veins,

which cut phyllites or metamorphic slates ; in the other the cassiterite is disseminated through more or less altered granitic rocks. This second type of lode deposit is the one which gives promise of commercial importance.

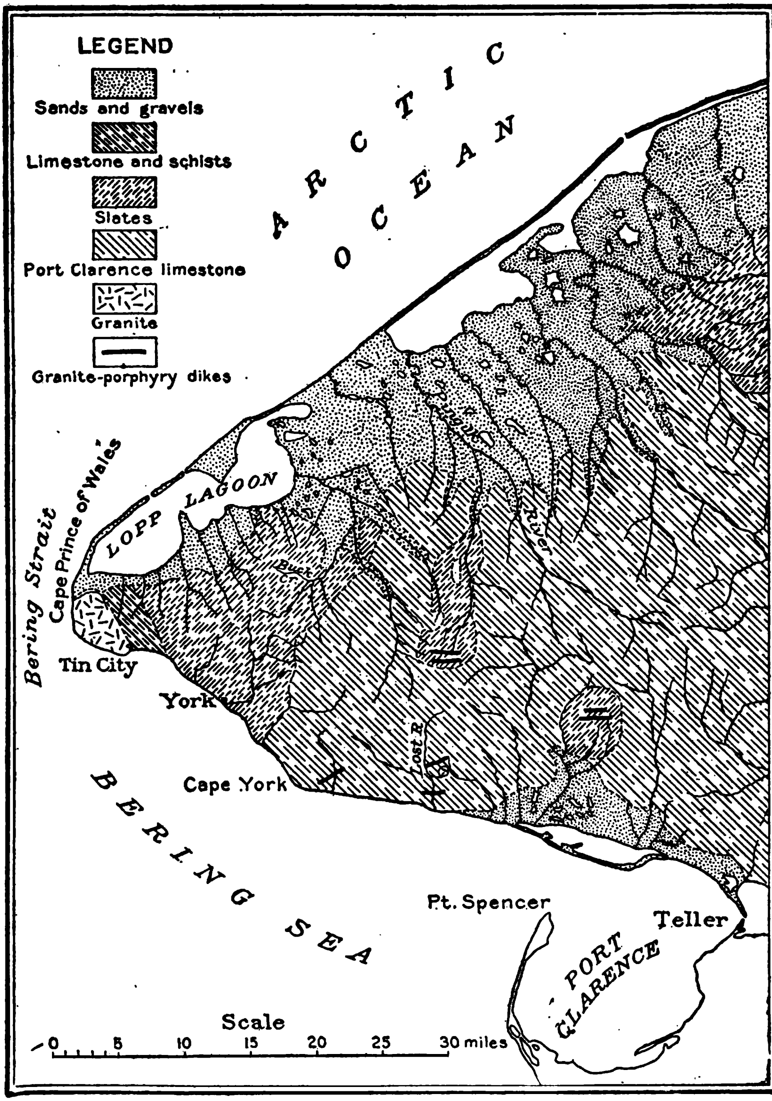


FIG. 30.—GEOLOGICAL SKETCH MAP OF THE YORK REGION.

In estimating the value of tin ores in this northern region, several facts should be borne in mind. The region is utterly without timber, and is accessible by ocean steamers only from June to the end of October at the longest. Harbour facilities are poor, and all supplies and wages are high. On the other hand, the construction of railroads and wagon roads is not difficult, and will require comparatively small outlay. All of the occurrences described are within a few miles of tide-water. Freight rates to Paget Sound ports should be very low, as the large fleet of ocean steamers which run to Nome return empty. Last summer upwards of 98,000 tons of freight were brought to Alaska by vessels that called at Nome. It is fair to say that these tin deposits are well worth careful and systematic prospecting.

CHAPTER XV.

MOUNT BISCHOFF TIN MINE.

THE Mount Bischoff Tin Mine is situated in the north-west of Tasmania, about 45 miles from the north coast; there is a gradual ascent nearly all the way. The top of the mountain where the mine is situated is 3,500 feet above the sea-level, and 1,200 feet above the surrounding table-land of basalt.

This mine was discovered by James Smith on the 4th December, 1871. While prospecting for gold and silver, he found a heavy, dark, resinous-looking substance in the bed of a creek; and presuming from its specific gravity that it was a metallic ore, he carried some of it to a distance of 54 miles to Table Cape in order to have it tested. There he learnt, somewhat to his disappointment, that the heavy mineral did not contain either of the precious metals, and was simply tin ore. Mining was begun in December 1872, and in August, 1873, the present Mount Bischoff Tin Mining Company was formed, with a capital of £60,000, in order to prosecute working on a larger scale.

The property at first consisted of 160 acres, covered for the most part with dense horizontal scrub; this consists of a tangle of twigs and branches almost impenetrable to the explorer, and often concealing soft and treacherous mossy bogs. As the carriage of supplies over the then existing rough bush track cost from £24 to £30 per ton, a road to the nearest port, Emu Bay, became a matter of necessity. In 1875 the work was completed, and though, owing to the imperfect method of construction and the excessive rainfall, it was impassable for nine months in the year, it nevertheless enabled goods to be carted to the mine in the dry season at a cost of £6 to £8 per ton. A horse tramway, constructed in 1884, reduced the freight to £5 per ton, and finally its conversion into the present railway of 3 feet 6 inches gauge brought about a further reduction to £3 per ton, which is the present tariff, except for specially rated articles.

The geological features are very interesting, and the origin of this remarkable deposit has been made the subject of much discussion. Mount Bischoff consists of contorted and greatly metamorphosed slaty rocks, which are traversed by dykes of topaz and quartz porphyry.

The surrounding plains are largely formed by sheets of basalt. Within an area of 1,100 yards by 600 yards around the mountain the dykes are of a stanniferous character; but beyond this distance they become more compact, harder, and less productive. The remarkable deposits of tin ore which form the wealth of Mount Bischoff are probably due to the disintegration of the stanniferous dykes.

Baron von Groddeck,* late Director of the Royal Prussian Academy of Mines at Clausthal, has carefully analysed the tin-bearing porphyries of Mount Bischoff, and he concludes that the tin matrix is not, as supposed, a quartz porphyry, but a porphyritic topaz rock, and that, like the topaz rocks at Auerbach in Germany, they form in themselves immense lodes of tin ore.

The Mount Bischoff † deposit has been more recently described by W. von Fircks in a paper, in which he writes as follows:—"The tin deposits appear in an area of quartzites and clay slates with dykes of quartz porphyry. Granite is present, but at some distance from the mine. These deposits are in part fissure veins carrying cassiterite, pyrite, arsenopyrite, fluorite, wolframite, tourmaline, and siderite. The latter mineral is notable because not usually present in veins of this character. Another part of this deposit is formed by replacement, chiefly of porphyry dykes. All rocks in the vicinity of the mine are much altered. The schists and slates contain a considerable amount of tourmaline and are in part changed to typical 'tourmalin-fels' by complete replacement, only a few grains of the original rock remaining."

Where the dykes have intruded into the schists, the rock has been much twisted and folded, and some remarkably clear anticlinal sections have been exposed in the various excavations and cuttings. In one instance a pure topaz dyke was discovered on the southern section of the mine. It was about 3 feet in thickness when first opened, and contained a high average of black ore.

A very noticeable feature is the presence of iron pyrites close to the surface in the "Slaughter-yard Face," while no pyrites was met with in the "Brown Face" until a depth of 200 feet was reached.

For the sake of convenience the deposit will be described in detail, in six bodies known locally as the Don and Stanhope Sections, White, Brown, Slaughter-yard, and Alluvial North Faces.

The Queen Lode, situated north-east of the brown face, is a separate body of ore, having an average width of 3 feet 6 inches, and gives a uniform return of 12 per cent. of tin ore. The production for the first half-year of 1904 was 142 tons.

The Brown Face has been so named from the colour of the deposit, and formed by far the larger portion of the payable ore worked. This face rests on a bed of slate at an angle of 35°, and the ore in this face has averaged about 2¾ per cent. of tin ore; it is a mass of stanniferous gozzan, and is probably the result of decomposition, *in situ*, of a large ore body consisting of iron pyrites and cassiterite. In several portions

* Johnson, "Geology of Tasmania," p. 221.
† Zeitschr. d.d. Geo. Ges. Bd. U., p. 433, 1899.

of the face large bodies of undecomposed pyrites exist, but their general average is lower than that of the gozzan.

The White Face is a deposit of detrital tin ore extending over a large space, the average thickness of which is about 25 feet; it contains from 2 to 3 per cent. of cassiterite fairly evenly distributed; in some parts the constituents are sharp and angular, and sometimes well rounded and water-worn. This deposit rests on a bed of micaceous clay of varying thickness, which again rests on a stratum of iron pyrites much decomposed near the clay; this pyrites rests on slate towards the north, but in the south part on the older alluvium, consisting of water-worn fragments of chalybite, iron pyrites, blende, and argillaceous matter; this older alluvium covers a considerable area on the south side of Mount Bischoff, but it is not, however, stanniferous.

It is not necessary to give a detailed description of the Slaughter-yard Face, which resembles the other faces, the only difference being the gozzans are more siliceous in character. On the Stanhope Section some large porphyry dykes are being worked; this ore, though very much harder than the gozzans, carries payable ore for 63 feet in width in places.

There has been some good alluvial found on the northern side of the mountain; the full length of the face opened here is 191 feet, with a depth of 144 feet. A cut on the east end was made 22 feet wide by 56 feet in height, and on the west another cut was made 23 feet wide by 56 feet in height. Near the surface of these cuts the wash was very good, especially the capping, which contained a fair percentage of nuggets of solid ore. The green lode situated north-east of the Brown Face is a separated body of ore, having an average width of 3 feet 6 inches, with a uniform return of about 12 per cent. of tin ore. At the 180 foot level bunches of pyrites have been met with, the ore up to this point being entirely free.

A tunnel has been driven underneath the Brown Face right through the mountain, but disclosed nothing of great value, as the Brown Face, at a depth of 260 feet, splits into innumerable veins, consisting mainly of iron pyrites carrying a little cassiterite.

About a mile to the north of Mount Bischoff a lode, known as the North Valley Lode, has been worked by the Bischoff Company; this lode varies from 1 to 5 feet in width, and near the surface is free from pyrites, but as depth is attained the ore becomes highly pyritic, the ore occurring in shoots which carry at times as much as 50 per cent. of cassiterite, but the average of the ore throughout is slightly under 1 per cent. Work has been suspended here for the time being.

The method of mining the ore is as follows:—The various faces and such portions of the porphyry dykes as are rich enough to work are mined as open quarries in the soft ground. Every miner can excavate from 10 to 12 tons of ore per day, but only about 4 tons in the harder porphyry dykes. The rates of wages are 8*s.* per day for miners, and 7*s.* to 7*s.* 6*d.* per day for truckers and labourers. The total cost of mining and delivering the tin stuff to the Company's dressing-sheds is 3*s.* 2½*d.* per ton. The water supply, although naturally good, has had to be artificially increased at the Waratah Works; for motive power

and dressing purposes a total of 41,600 gallons of water are used hourly; this is drawn from the Waratah River and the Fall Creek, on which extensive reservoirs have been constructed. They have been formed by building embankments across the gully, and have a storage capacity of 490,000,000 gallons, and a total sum of £22,395 has been spent on the increased water supply.

**Dressing.*—The principal dressing works are at Waratah, a place conveniently situated as regards water supply, about 1¼ miles from the mine. At the mine the coarser stuff is reduced in a jaw-breaker to a diameter of 2½ inches, and is then deposited in hoppers, to which the fine stuff is run direct. From these hoppers the ore is taken in bottom-discharging trucks to the dressing works, on a railway of 3-foot gauge, with steel rails weighing 46½ lbs. to the yard. This has been worked by a locomotive since 1879, when it took the place of a previously existing horse tramway. The cost of transport by the horse tramway was 4¼*d.* per ton; now it is but slightly more than 1*d.* per ton.

The tin ore brought by the locomotive is first passed through stamps, and is then sorted by up-current rising classifiers into coarse and fine qualities, which are jigged in two-compartment jiggers. The overflow from the classifiers flows to settling tanks, from which the slime passes to rotating tables, and the overflow to the concave buddles which are placed on the lower floor. From the rotating tables the concentrates are delivered into troughs, and are afterwards re-treated on tables and finally keeved, while the tailings are led to buddles. The heads from the buddles are re-buddled and finally cleaned in a keeve. The concentrate from the first compartment of each jigger is clean ore ready for the smelter; it is caught in troughs underneath the jiggers. In the second compartment a mixed product collects, consisting of cassiterite with adherent waste; this is removed by a hydraulic-jet elevator and is jigged a second time, while the tailings are concentrated by buddles, the concentrate being pulverised in one of two Chilian mills, then cleaned on rotating tables and buddles, and finally prepared for the smelter by keeves. From the second jigging the concentrate goes to the smelter as second-class ore, while the tailings go to the Chilian mills above mentioned. The whole of the tailings are re-worked in separate sheds, where, after classification, the sand goes to buddles and the slime to rotating tables.

The stamps are of the Californian type; there are three batteries of forty, twenty, and fifteen heads respectively. The moving part of each stamp weighs 5 cwt., the lift is 8 inches, and the number of blows 72 per minute. There are five heads in each mortar-box, the order of lift being 1, 4, 2, 5, 3. The screens are of woven steel wire, with 196 holes to the square inch (14 mesh), two to each box; they are 19 inches long by 12 inches wide, and require renewal every eighteen days. The shoes, which weigh when new 128 lbs. each, have an average life of six months; the dies, of 70 lbs. weight each, require renewal once a year. Although the water acts corrosively on the shoes

* Kayser and Provis, "Trans. Inst. of Civil Eng.," Vol. 123, Part I.

and mortars, the tin-stuff is more easily stamped than ordinary Cornish tin-capels. The crushed ore does not discharge freely on account of its adhesive nature; and consequently only sufficient water is used to produce a good splash, more water being added to the pulp before it reaches the classifiers. During the dry season, when water is scarce, shoes of 64 lbs. weight are used. This method of reducing the amount of ore dressed is better adapted to the arrangement of the works than stopping a part of the plant.

It is necessary to mention that the tin ore is associated with other mineral substances, which have specific gravities only slightly inferior to it, and that therefore careful classification is imperative. There are in all thirty of these classifiers, and they are used in tandem pairs; the first separating coarse sand, while the overflow carries away the slime. They are constructed of pine boards, $1\frac{1}{4}$ inch thick, tongued and grooved. Water under pressure is brought into a horizontal pipe under each classifier; the pipe and the classifier being connected by a vertical pipe through which water flows upwards, and the classified product downwards. The latter is delivered into a jigger by a vertical pipe attached to a prolongation of the horizontal pipe. The mouth of the delivery pipe is 12 inches above the bottom of the classifier. In the horizontal pipe, between the classifier and the jigger, is a "gauge piece," which is simply a short iron block, screwed at both ends, and bored with a hole $\frac{3}{16}$-inch in diameter, inserted to prevent an undue quantity of the water going to the jigger. This device is a great improvement on the ordinary cocks formerly used, which suffered so much from the wear of the sharp sand that they became inefficient in a day or two. A wooden plug in the end of the horizontal pipe and the hand-valve are both provided in the event of the appliance becoming choked.

Jigging is performed through the sieve, and there are thirty two-compartment Hartz jiggers. The cases are of $2\frac{1}{2}$-inch pine, tongued and grooved, the whole being held together by $\frac{1}{2}$-inch bolts. The sieves are 2 feet 6 inches long by 1 foot 6 inches broad; woven steel wire of fine mesh rests for support upon a stouter sieve, the two being attached to a wooden frame which rests upon an iron grid, and is held in position by a bar fixed above it. The pistons are of wood, and are caused to reciprocate by eccentrics, the throw of which can be altered at will. The arrangement is similar to that already described by Mr. E. du Bois Lukis.* The connecting rod is made in two pieces, united by a long coupling nut, so as to allow easy access to the interior of the jigger without interfering with any other part of the machine.

The hydraulic-jet elevators used to convey the mixed products from the second compartment of the first jiggers to other jiggers are shown in detail (Fig. 30). This system of continuously withdrawing the concentrates from the second compartment, and saving the second-class ore separately, enables a better-dressed product to be obtained from the

* "The Separation of Galena and Blende from their Gangue as practised at the mines of Sentein, Arlege, France," Minutes of Proceedings Inst.C.E., Vol. LXXXV. 1885-86, p. 364.

first compartment; it also acts as an indicator of the regularity of the working of the jigger, any irregularity being shown by a variation in the amount of discharge from the second compartment. The jets work

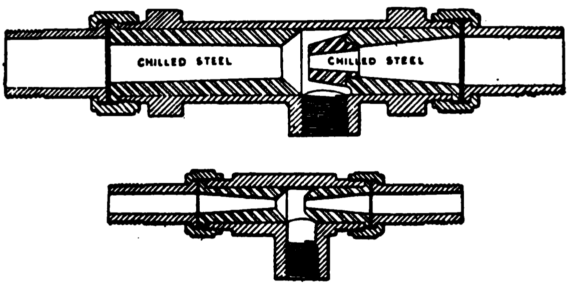


FIG. 31.—SECTION OF HYDRAULIC JET ELEVATOR.

silently and with little attention; the nipple, the only part liable to get out of order, can be replaced in less than five minutes. The jiggers working on coarse sand have sieves with 144 holes to the square inch (12 mesh), and are driven at 160 strokes of $\frac{3}{16}$-inch per minute; while those on fine sand have sieves with 196 holes to the square inch (14 mesh), and make 202 strokes of $\frac{1}{8}$-inch per minute. The sand delivered to the jiggers carries 5 to 12 per cent. of tin oxide, and the jiggers save between 65 and 75 per cent. of the output from the Waratah works; the ratio of second-class ore to first class being 1 in 10. It is necessary that both sand and water be fed to the jiggers with the utmost regularity, that the classification be efficient, and that the fragments of ore constituting the bed be of uniform size.

There are thirty-nine convex rotating tables in use for treating slimes. They are similar in principle to the first table described by Mr. R. E. Commans in a Paper* read before the Institution of Civil Engineers. The surfaces of the tables are now made of cement, as it was found impossible to keep the wood surfaces previously in use sufficiently even. The frame is of wood, on which is fastened sheet iron, $\frac{1}{16}$-inch thick, to carry the cement surface, which is 1 inch in thickness; an even edge at the circumference being secured by a tire of $\frac{1}{2}$-inch pine. When the cement is well set, it is strong enough to support its own weight; and, although the sheet-iron foundation corrodes, and in course of time altogether disappears, the efficiency of the table is in no wise impaired. A coating of a mixture consisting of 25 per cent. turpentine and 75 per cent. coal tar is laid on with a brush when the cement is sufficiently dry to absorb it. This prevents the corrosion of the surface, which was found to take place before this precaution was adopted. The coating requires renewal only once in two years. The tables vary in diameter between 10 and 15 feet, and the slope of the surface is 1 in

* "Minutes of Proceedings Inst.C.E.," Vol. CXVI., 1893-94, p. 57.

12. The slime deposited on the table is swept off at the required points by jets of clean water. The tailings are removed by the first jet, and afterwards the concentrates, two classes being made in the first treatment of the slime, and three in the final treatment of concentrated slime. In order to enable the attendant to vary, as necessary, the point at which each jet of water strikes the table, the nipple is bored at an angle to its axis, so that by slightly turning it round the direction of the jet can be changed. The jets at each table require 23 gallons of clean water per hour. Frequently two or three tables are mounted on one axle; and when space or motive power is limited, this arrangement is to be recommended. In the case of a double table, the concentrate made by the upper table is further cleaned by the lower one, and with favourable ore this may be sufficient treatment before the final tabling; but when the ore is more difficult to treat, a third operation may be necessary, and this is especially the case with very fine slimes.

The tables are rotated by worm-gearing once in 2½ minutes; and a single table will treat 7 cwt. of slime per hour, requiring ⅛ horse power to drive it. The double and triple tables consume very little more power than the single tables. The slime, as delivered to the rotating tables, carries between 0·1 per cent. and 1·0 per cent. of tin ore, and the first concentrates contain between 15 per cent. and 20 per cent. Of the total output from the works, 15 per cent. to 20 per cent. is saved by the tables. The cost of constructing and erecting a single table is about £93 at Mount Bischoff, where labour and materials are alike expensive.

There are 17 Kayser concave buddles. They are similar to those of the Munday type, except that, while in the latter the two scrapers attached to each arm sweep out two separate circles, in the former the two circles overlap, and so enable the process to be more efficiently controlled. They are between 14 feet and 20 feet in diameter, and, working at a speed of 6½ revolutions per minute, require ¾-H.P. each. The slime and sand feed to the buddles contain about 0.25 per cent. of ore. The first buddling raises this to 7 per cent., and by rebuddling the percentage of ore is raised to 60 per cent. The buddles contribute 4.75 per cent. of the ore saved in the works.

Motive Power.—Seven overshot water-wheels, ranging from 18 feet to 40 feet in diameter, supply the necessary power for driving the machinery at the Waratah works. They are so placed, one under the other, that the water which passes over the top wheel goes to the second, and then to the third, and so on to the last. These wheels furnish 200 horse-power. Overshot wheels are used in preference to turbines or Pelton wheels, because they require less skilled supervision; further, because the water employed comes from other dressing sheds above and is more or less charged with sand, which would quickly wear out either of the two latter machines.

Lighting.—Incandescent electric lamps are employed; a 120-lamp dynamo serving to light the works, workshops, and offices. The annual cost, for maintenance only, of 75 16-candle power lamps is £47 17*s.* 6*d.*;

while 37 12-candle power kerosene lamps, which were formerly in use for lighting the dressing sheds, cost for maintenance £112 14*s.*

Cost of Dressing.—In the Bischoff dressing sheds there are 37 men and boys employed, 13 day, 12 afternoon, and 12 on night shifts. They are employed as shown in the following table :

		s.	*d.*
1	Attending machinery and supervising	9	2
3	Feeding 60 heads of stamps, each	8	0
1	„ 15 heads „ „	7	6
3	Attending jiggers, each	7	6
2	„ tables, „	5	6
1	„ buddles „	5	6
1	„ tables and buddles and lime sheds	5	6
1	Day shift—general work	8	0

The cost of stamping, dressing, bagging, and delivering the ore at the railway is 1*s.* 1$\frac{1}{8}$*d.* per ton of stuff treated ; this includes labour, lighting, oil, grease, repairs, and renewals. About 6,000 tons of ore are treated every month.

The average per cent. of ore obtained from the whole mine is 1·322. The cost of mining, crushing, and dressing a ton of stanniferous material is as follows :—

	s.	*d.*
Mining, including new works, maintenance, and other expenses	2	10·836
Filling, hauling, and emptying trucks	0	5·566
Crushing, dressing, and maintenance of plant	0	9·962
Slime sheds	0	1·171
Ringtail sheds	0	2·111
Management and supervision	0	7·479
Plant, including all machinery	0	2·052
Development and progressive work	0	2·627
Diamond drilling	0	7·224
Waterworks	0	0·031
Ore bagging	0	0·527
Stores	0	5·630
Sundries	0	0·717
	6	7·933

The dressed ore is sent to the company's smelting works at Launceston, a distance of 160 miles, in two qualities ; No. 1 quality assaying, on an average, 70½ per cent. metallic tin, and No. 2, 65 per cent. It does not pay to dress cleaner than this, as the cost of extra labour, and the additional losses incurred, would more than counterbalance the increased value of the purer ore.

Tailings and Loss.—After the tailings leave Waratah works they are again treated, together with those from two neighbouring companies' works, at the "Catch 'em" sheds, ¾ mile further down the stream Here they are first buddled, then crushed in a Chilian mill, classified

and treated on rotary tables. One man and one boy are employed in each shift, and about 50 tons of ore are saved annually. Numerous assays have been made to ascertain the amount of cassiterite in the tailings after they have been finally discharged; but the results differ according to the source of the tin-stuff. The material from the White Face is easily treated, and the loss is extremely small; but it is more difficult to extract all the ore from that yielded by the Brown and Slaughter-yard Faces—the difficulty apparently bearing some relation to the amount of hæmatite present. Samples taken every day for a fortnight averaged between 0·01 per cent. and 0·2 per cent. of tin, the higher limit being reached only in one sample.

Auxiliary Works.—Until recently some alluvium was partially dressed at the mine by sluicing. The concentrate, which contained about 20 per cent. of tin ore, was sent to the Waratah works for final treatment; while the tailings from the sluices were re-treated at the Ringtail works, situated a little below the mine. Now most of the material adapted for this treatment has been worked out, the sluices are no longer used, and the Ringtail works are only run occasionally to treat the tin-stuff washed down with the drainage from the mine. There is another dressing establishment at North Valley, which, although smaller, only differs in general arrangement from the Waratah works in that it has a calciner for roasting the ore which is pyritic.

The inconvenience due to the distance of the mine from all engineering works led to a brass and iron foundry being established at Mount Bischoff in 1887. This has proved extremely useful, both in preventing stoppages and in enabling old material to be worked up again and mixed, so as to produce metal best suited to the particular purposes in view. A No. 1 Root-blower provides the blast, and also blows four fires in the smithy. A telephone connects the office with North Valley, 3 miles away, the Ringtail dressing-sheds, the mine, and the manager's house.

Ore obtained since the formation of the company, 65,376 tons 18 cwts. 2 qrs. 2 lbs.

Total dividends declared to 30 June, 1906 (including No. 351), £2,061,000.

In November, 1906, the output of the Mount-Bischoff Company was reduced from 100 tons of ore a month to 60 tons. This was caused by the exhaustion of the richer ore without making due preparation and alterations in the dressing plant necessary to treat the large masses of low-grade ore profitably. A new electric power plant is being installed, and a more up-to-date mine equipment. This will have the effect of reducing the working costs per ton, which have been steadily rising for some years past.

Tin Dressing.—Ore treatment at Mount Bischoff, Tasmania. Donald Clark outlines the Mount Bischoff tin concentrating plant.* The system used is as follows:

(1.) Stamps (896 lbs.) with 14-mesh screen, stamping 4 tons per stamp per 24 hours; the pulp goes to (2).

* "Australian Mining Standard." Vol. XXIX, 1903, p. 432.

(2.) Spitzluttn, yielding spigot product to (3) and overflow to (4).

(3.) Five No. 1 Hartz jigs, yielding concentrates to a bin, middlings to (5) and tailings to (6).

(4.) Spitzkasten yielding first, second and third spigot products to (9), overflow to waste.

(5.) Five No. 2 Hartz jigs yielding concentrates to bin, middlings to (8) and tailings to (6).

(6.) Five buddles yielding concentrates to (7) and tailings to waste.

(7.) Chilian mill; product to (8).

(8.) Five slime tables yielding concentrates to (9) and tailings to waste.

(9.) Five Kayser ore-dressing tables, yielding concentrates to (10), tailings to waste.

(10.) Dolly tub, concentrates to bin.

CHAPTER XVI.

THE DOLCOATH TIN MINE.

THIS mine is still the largest tin-producer in Cornwall, and has during the 150 years of its existence produced minerals to the value of over £6,000,000; it was known as an ore-producing mine as early as 1746, and has been worked successfully for both tin and copper. It is now, however, exclusively a tin mine; an interesting fact is that it is probably the only mine in existence that has been managed by one family for three generations.

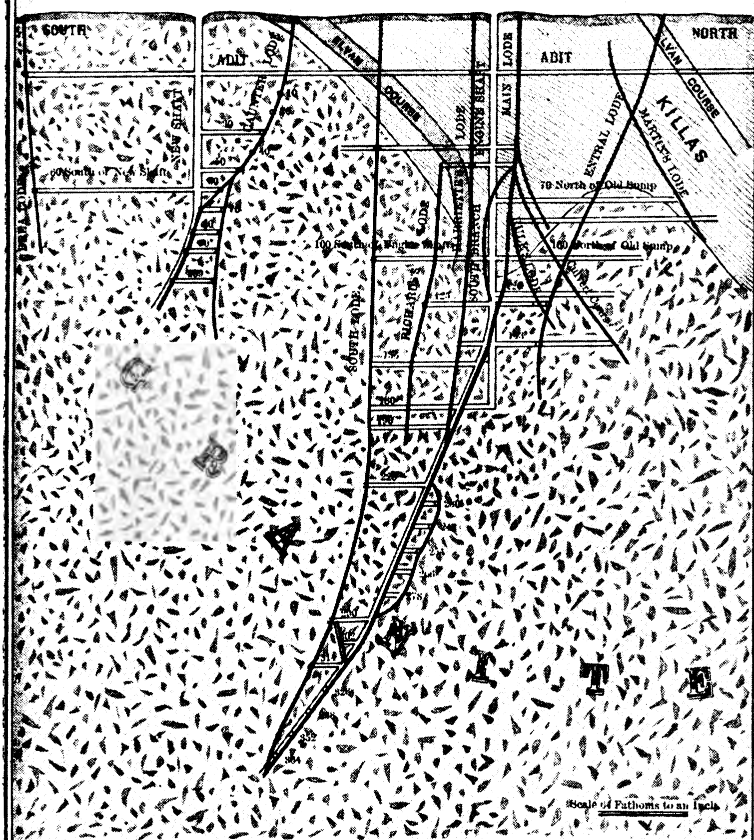
The present company operating the mine was formed in 1895 with an authorised share capital of £350,000, and has erected the present mining and dressing plant; also conducted the mining operations on an extensive scale.

Mr. R. J. Frecheville gives the following particulars of the Great Main Lode of Dolcoath. (Trans. Royal Geo. Society of Cornwall, 1887.)

To the south of the town of Camborne, where the killas overlaps the northern base of the granite range of hills known as Carn Camborne, Carn Entral, and Carn Brea, the formations are traversed by the great main lode of Dolcoath, Cook's Kitchen, Tincroft, and Carn Brea Mines, which, together with its branches, produces about one-third of the total amount of "black tin" raised annually in the county, and is now being worked on continuously for a distance of about 2½ miles along its course, and to a depth in Dolcoath Mine of 485 fathoms, from surface on the "underlay," or 355 fathoms perpendicular.

The "strike" of this great lode, which goes by the name of the Main Lode in Dolcoath, Chapple's Lode in Cook's Kitchen, and the Highburrow Lode in Tincroft and Carn Brea Mines, is about 30° north of east, approximating closely to that portion of the line of the West Cornwall Railway connecting the towns of Camborne and Redruth. Its "underlie" is to the south, and varies considerably, being much flatter in the deeper workings than it is nearer surface. Thus in Dolcoath Mine, from the 200 fathoms level to the bottom of the "sump," the "underlie" is 4′ 6″ in the fathom; and in Cook's Kitchen Mine from the 190 to the 345 fathoms level, it is 3′ 3″ in the fathom; whilst in both mines in the levels above the "underlie" averages about 2′ in the fathom.

CROSS SECTION OF DOLCOATH MINE.



In the "country" south of the main lode there are several powerful branches also "underlying" south, but steeper than the main lode, so that in time they drop into it and serve to enrich it. Of these the most important are Dunkin's Lode and the South Lode, the former being known as Teague's Lode in Carn Brea.

These lodes all "crop up" within the killas ground at surface, but penetrate the granite at various depths, ranging from about 80 fathoms from surface at New Shaft in Carn Brea to about 130 fathoms from surface at the engine-shaft in Dolcoath, the line of division between the granite and killas thus appearing to incline to the north-west.

In the following remarks on the mines in which the main lode is being worked, the numbers prefixed to the levels signify their depth in fathoms on the "underlie" of the lode, taken from the adit level, which comes in at from 20 to 30 fathoms from surface.

In Camborne Vean, the western mine of the group, the engine-shaft has been sunk on the main lode to the 180. From that level a cross-cut has been driven to the south lode, on which a shaft has been sunk to the 282. Operations are now, however, confined to above the 140, to which level the mine is drained by Stray Park engine. The lode shows itself here strong and masterly, composed chiefly of capel (schorl-rock), quartz, and peach, with a very small admixture of tin oxide.

At the 364 level the lode in the Dolcoath Mine was about 20 feet wide, and a large proportion of the lode-stuff, both here and in the bottom of the shaft, contained an average of about 10 per cent. oxide of tin to the ton of stuff.

The cross section, which is taken through the engine shaft, shows the branches which have dropped into the main lode from surface down. The great improvement in the bottom levels may be ascribed to the influence of the south lode, itself a most important lode, which fell into the main lode at the 375 level. There are, however, two points connected with Dolcoath that are to a certain extent overlooked. East of New East Shaft the main lode is standing almost intact from the 230 down, the south lode having been chiefly worked on in this portion of the mine. Again, west of Old Sump Shaft below the 190, there has hardly been anything done on the south lode. Now, there can be little doubt, judging from the developments made on the main lode at the 352 level east of New East, and on the south lode at the 364 level west of Old Sump, that these unexplored portions of the mine contain valuable runs of productive ground.*

The characteristics of the lode stuff in Dolcoath are that the richest ore consists of a compact, bluish-coloured rock, consisting of a mixture of peach, quartz, and schorl, with strings of oxide of tin running through it, while the poorer parts are more capelly and of a blacker colour. Where chiefly composed of quartz the lode is very poor. In the 100 shallower levels the lode was much harder than it is at present. On the north or "foot-wall" side the lode has always a distinct and

* At present the New East Shaft has been sunk to the 455 fathom level, and the mine has been extensively developed and worked from here.

definite wall; whilst on the south side it passes gradually into non-stanniferous granite, without any clear and definite bounding-plane.

The granite in the deeper portions of the mine has a bluish colour for a couple of fathoms from the lode, and after that a greyish colour. East of New East Shaft at the 352 level, for about 50 fathoms in length on the south lode, the granite on the hanging-wall side is quite soft and decomposed, so that the level has to be closely timbered; and the lode presents, considering the depth from surface, an extraordinary appearance. It is full of "vugs," can be broken with the pick alone, and, being stained of a reddish colour with oxide of iron, looks, as an old miner remarked to me, just like the "back" of a lode. On the foot-wall underneath this soft ground the lode is extremely rich, and shows signs of great tranquillity, the peach, quartz, and tin oxide lying more or less in parallel layers. Luckily the occurrence of this very soft granite enclosing the lode seems to be quite local, the end of the 352 level east being now driven in hard ground. The granite showing in the 364 level and in the bottom of the engine-shaft is also hard and firm.

Cook's Kitchen Mine, to the east of Dolcoath, is separated from the latter by a cross-course filled with decomposed granite and clay, between 8 and 9 feet wide, nearly perpendicular, and coursing about north 40° west.* This cross-course heaves the lodes from 70 to 80 fathoms to the right.

J. H. Collins, in his "Origin and Development of Ore Deposits," gives the following account of the Dolcoath Mine:—

The average width of the Dolcoath lode is certainly much greater than the average of the lodes of tin and copper in the west of England as given by Mr. Henwood. From the 66 to the 197 in Dolcoath it was about 6 feet, but narrowing in places to 1 foot, and widening in others to 16 feet. At the present bottom of the mine it varies between 2 and 4 fathoms, with perhaps 16 feet for an average; the tinny portions being mostly wider than those containing only copper, as already stated. In Cook's Kitchen, Tincroft, and Carn Brea Mines, the present average is somewhat less. On the whole I think we may safely take the mean width of the whole lode at 6 feet for the coppery portions and 10 feet for those yielding tin (of which the leader or actual fissure filling will not average more than one foot) for the whole period since the mines have yielded tin. The lode in the lower levels has widened out, and is now being worked from 20 to 40 feet wide, the quality of the ore being much poorer.

The walls in the great lode are generally fairly distinct, but less so in depth than nearer "grass." The hanging wall is generally better defined than the footwall, especially in the deeper workings. Vugs and cavities were much more common in the lode in the shallower

* Richard Thomas, "Report on a Survey of the Mining District of Cornwall from Chasewater to Camborne," 1819.

than they are in the deeper workings, but they are still occasionally met with in all the mines on the lode.*

The contents of the lode have, as already stated, varied at different depths. In the shallower portions above adit there was much gozzan, consisting of earthy brown iron ore with iron pyrites and spongy quartz, and in places earthy black copper ore, with various rare crystallized arseniates and phosphates of iron and copper, also much chalcopyrite and chalcocite. In the eastern part of the mine a good deal of tin was raised from the shallower workings. Some of the earthy brown iron ore was found as far down as the 197 fathom level. The rich parts, while yielding copper, usually gave it as chalcopyrite with few crystals. Soon after reaching the granite most of the copper gave out and the mine changed to a tin mine. The richest ores of tin are of a bluish colour, not very hard but quite compact, and permeated in all directions by strings of rather light-coloured oxide of tin. Often this bluish rock passes into a dark red ferruginous mass without becoming poorer in tin. Careful microscopic examination shows that the blue tin-stone, apart from the tin, consists of quartz, chlorite, and schorl—the latter mostly in minute needles; and the change from blue to red seems to be a subsequent oxidation change of the chloritic portion of the mass.† The poorer parts of the lode are very similar, except that they are very much harder and more siliceous, and with a tendency to a black or light blue colour.

The country rock changes noticeably with the lode matter. The killas is fairly soft near the surface; it generally becomes harder as it approaches the granite, but is always soft near the rich parts of the lode; above it is often yellow or buff in colour, below mostly deep blue. While the granite remained very hard, the lode was not productive either for tin or copper—it is now in general fairly soft and moist, the felspar much kaolinized and often accompanied with pyrites and red oxide of iron.

The curious alternations of killas and granite which this great lode cuts through have been noticed by many writers. In 1882 "a large mass of hard slaty rock was met with in the 352 fathom level east of the eastern shaft . . . included in the granite 240 fathoms below the point where that rock was first cut into by the workings . . . this resembles the ordinary killas of the district, and on comparing thin sections of the two under the microscope their identity becomes at once apparent."‡

The imagination is struck with the figures expressing the extent

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* In November 1814 a cavern was discovered in the main lode at a depth of 170 fathoms. It was from 18 to 20 fathoms high, and from 4 to 9 fathoms wide. It contained much loose material which had fallen from the sides, and communicated by narrow channels with many subsidiary cavities. *See* "Trans. Roy. Geol. Soc. Corn.," Vol. I. Similar vugs have been found in nearly all the master lodes of the West of England. The present manager of Dolcoath, Mr. Arthur R. Thomas, informs me that the deep levels do not bear out Mr. Collins deductions, as there are no well-defined walls, and he would rather class the deposit there as a big zone of impregnation.—S.F.

† *See* "Cornish Tin-stones and Tin-capels," plate IV., figs. 3–4.

‡ Phillips, "Ore Deposits," pp. 131–2.

and produce of this great lode. But if we look at the facts in another way, as suggested by M. Moissenet, we shall see how insignificant a feature it forms in the earth's crust. "Let us suppose a model of the lode made to a scale of one-thousandth the real size—it could be easily made from a sheet of lead 12 feet long and 3 feet wide. In many places the thickness would have to be reduced to a mere film, but in some it would require to be thickened up to a quarter of an inch or a little more. The sheet might be placed on edge, its length in a direction nearly north-east, south-west, and with a considerable dip to the southward. If now it were bent lengthwise in such a way that the thicker portions were more nearly east-west, and the thinner more north-east, south-west, and also bent in width so that the thicker portions stand more nearly vertical than the thinner, and the lower portions more nearly horizontal than the upper, it would very fairly represent the relative proportions of the lode and also its position in the ground.* Viewed in this manner the vast and richly filled subterranean channels, which by the implements of the miner are transformed into caverns of imposing extent, appear what they are—as thin veins in the ground."

Some of the stopes are of an immense width, which has necessitated a hanging tram-road, a feature in the mine, as not much timbering is required, the country rock being very hard.

The system of working by contract in the stopes is carried out, and also in the developing work in the mine, the contractor supplying explosives, rock drill, tools, and all labour at a fixed price for ore delivered at the shaft, the company supplying the power for the rock drill and paying all winding expenses. Contracts are mainly set to a group of men (pare), generally 18, who break the tin-stuff and deliver it to the surface free of all charges to the company, who, however, supply the men with stores, explosives, candles, etc., at cost price, and charge the winding costs to the pare (this is the local name for the contract party of miners). The development work is chiefly carried out by contractors, who supply their own rails, drills, and general stores, the company supplying the compressed air free of charge.

OUTPUT OF DOLCOATH MINE.

	Tons of Black Tin.		Tons of Black Tin.
1888	2,239	1898	2,302
1889	2,215	1899	2,084
1890	2,027	1900	1,962
1891	2,132	1901	1,968
1892	2,536	1902	1,657
1893	2,421	1903	1,687
1894	2,126	1904	1,705
1895	1,766	1905	1,697
1896	2,038	1906	1,748
1897	2,095		

* The actual fissure or leader, apart from its metalliferous capels, might be represented on the above-mentioned scale by a sheet of paper thickly or thinly coated with lead on each side, in accordance with the dimensions given above.

Photo by] [*Burrows, Camborne.*

HANGING TRAMWAY, DOLCOATH TIN MINE.

Table of the Result of Stamps on Dolcoath Tin Mine, Cornwall.

(From information supplied by Mr. John Rowe, Engineer to the Company.)

Speed.	Pneumatic Stamps.	Californian Stamps.	Cornish Stamps.
Speed - - -	138 blows per minute.	90 blows per minute, ordinary cams.	70 blows per minute; revolving axle with three cams, 14 revolutions per minute.
Drop - - -	10 inches - -	10 inches - -	10 inches.
Screens - -	400 mesh (37 Cornish).	400 mesh (37 Cornish).	400 mesh (37 Cornish).
Feeding - -	Challenge ore feeder.	Challenge ore feeder.	Hand fed.
Weight of stamp -	1,250 lbs. - -	950 lbs. - -	850 lbs.
Result for 24 hours' stamp	20·1516 tons -	32 cwt. - -	22 cwt.
Continuous run of 635 hours for one stamp.	533·333 tons - 533 tons 3 cwt. 0 qr. 3·584 lbs.	42·272 tons - - 42 tons 5 cwt. 1 qr. 18·48 lbs.	29·104 tons. 29 tons 2 cwt. 0 qr. 8·96 lbs.
Cost of crushing per ton.	16·311*d*. - -	20·203*d*.	22·76*d*.

One Pneumatic Stamp equals 11·8 of 950 Californian Stamp.

950 lbs. Californian Stamp is the one used on the Rand, crushing 4 tons per 24 hours.

The manganese jaw-rock breaker lasts 4 months on the Dolcoath and 10 months on the Rand.

*On Crushing and Concentration at Dolcoath Mine, Cornwall.**

Previous to the installation of frue vanners, the usual system of tin dressing in Cornwall was in vogue at Dolcoath Mine.

After stamping, the pulp was, up to a few years ago, passed into "strips" immediately in front of the Cornish stamps, these strips being troughs about 20 feet in length and 18 inches in width and depth, having an incline of about 1 in 30. A partial concentration was thus effected, and a considerable proportion of the slimes separated by overflowing.

Three products resulted from this operation, which were further dressed in buddles. The slimes passed direct into settling tanks, and after a sufficient time had elapsed for proper settlement were treated

* R. Arthur Thomas, "Trans. Inst. of Min. and Met.," March 15, 1899.

over self-acting frames, the concentrates from which were again settled and further treated by girls over dead frames. The first products from this washing were "buddled" until the heads contained about 25 per cent. black tin and then calcined.

The "strips" have been entirely dispensed with, the pulp now being passed into a classifier, the fines from which are concentrated on a revolving table, thus dispensing with the slime treatment mentioned above. The table has a slow revolving bed sloping towards the centre, and is divided into two parts, in order to make two classes instead of one as previously. The inclination varies, but as a rule is 1 : 12.

The overflow from the revolving table on being settled contains enough slimes to be automatically treated at a profit over self-acting frames.

The coarse sand from the classifier is run through an ordinary buddle, from which three products are obtained : (1) heads, (2) middles, and (3) tails.

The "heads" are usually sent at once to the calciner. The second and third products are again "buddled" until a sufficiently high product, about 25 per cent. black tin, is obtained, which is calcined.

Brunton's calciner, the type in use, is a rotary furnace revolved at varying speeds, depending on the nature of the stuff to be roasted.

After calcination the concentrates are again buddled and "kieved," until a marketable product is obtained.

The buddle separation shows fairly good results, but entails an excessive amount of labour ; the system can only be defended on the ground of being already established, or the difficulty in obtaining the necessary capital required for making a change for the better. And again, the actual is greater than the apparent loss in treatment, because of the many re-handlings of intermediate products. As a result of the introduction of more automatic machinery, apart from the frue vanner plant, considerable reductions have been made in the cost of extraction.

About 12 months ago experiments were made with the idea of still further reducing this amount of labour, and getting by automatic machinery sharper separation, and consequently more economical results. In these experiments two systems of dressing were tried :—

(1) Classification, and subsequent treatment of the fines over a convex revolving buddle, and the roughs over two percussion side-inclined belts.

(2) A single treatment over vanners without classification.

In order to test the capacity and efficiency of the various machines, the trials were carried out on tin-stuff varying in character and value, and extended over a period of three months.

Two 4-foot vanners took the pulp from a five-stamp mill, the ore in every case being carefully weighed, sampled, and assayed.

Ten stamps supplied the pulp for the other machines. The concentrates from all the machines were weighed, sampled, and assayed. The percentage of extraction was thus accurately ascertained.

With the first system very good results were obtained, but too many products requiring further re-treatment, and further consequent losses, were produced.

As the vanner in taking the pulp direct from the stamps without any handling or classification produces a good clean concentrate at one operation, which is higher than that made by the other machines, and with small loss in the tailings, it was found to be the most suitable.

The mill crushing for this vanner plant consists of 60 stamps of the ordinary Californian pattern, and fitted with suspended Challenge feeders and a few roller feeders.

Forty of them have a falling weight of 850 lbs., the other 20 heads 1,050 lbs. each.

In addition to the 60 heads, there are two heads of Husband's pneumatic stamps, having a capacity equal to about 20 heads of the California 850 lbs. stamps. The mill is, therefore, equal to 80 stamps.

The motive power is a horizontal compound condensing engine, having cylinders 17-inch and 28-inch and 48-inch stroke, made by Price. The horse-power developed is 143. Steam is supplied by three Cornish boilers, each 6 feet by 30 feet, working at a pressure of 100 lb. per square inch. These boilers have recently been fitted with Meldrum furnaces, in order to increase their steaming power.

Steady driving being absolutely essential for the vanners, an engine 10-inch by 14-inch stroke, vertical type, was erected to do this work alone. This engine condenses in the compound engine condenser. A pumping engine (horizontal) and an electric light installation are used in connection with this plant. The engines are in one engine room, and are under the control of one man in each shift.

The ore is screened, selected, and crushed to 1½ cubic inches in the stone-breaking and sorting shed, near the main winding shaft, and is then trammed into the mill ore bins. Owing to the extreme hardness and toughness of the ore, great difficulty has been experienced in getting jaws to stand. Manganese steel is now being used with good results.

The stamps are set with an 8-inch drop, and are run from 85 to 90 blows per minute. Punched copper screens (round holes) are used in the mill, and are No. 37 Cornish mesh, equal to 27 wire mesh. As the bulk of the loss of tin occurs in the slimes, it is a point of great importance to arrive at the limit of the mesh of the screens and weight of stamps with efficiency of subsequent extraction. Experiments are now being made to determine whether by still increasing the weight of the stamps more slimes will be produced.

The average daily crushing of the whole mill is 125 tons (2,240 lbs.).

Various forged and cast steel shoes have been tried, but hard cast-iron made by local founders have worked out at a lower cost per ton, allowing for re-melting of the old castings when worn down.

The tin ore is exceedingly difficult to crush, as it contains but a small percentage of friable quartz and a very large proportion of tin capel, which is both hard and tough.

The poorer grade ores are the hardest, and contain the greater proportion of fine tin. With the present price of black tin 1 per cent. ores are profitably worked with this plant. The richer ores crush faster, and need more careful concentration.

The vanner plant consists of 27 6-feet machines with plain belts, having Brownell patent flanged edges.

In the preliminary trials of corrugated belts against plain belts, the former were found to bring up too much coarse material, reducing the percentage of tin in the concentrates.

An ample number of vanners has been laid down so as to efficiently handle the pulp when the mill is crushing the highest grades of ores.

The method of dressing adopted is a single treatment on vanners, with re-treatment of the tailings after classification, the slimes on revolving buddles, the coarse by concentration and pulverising.

One side of the mill, consisting of six batteries of five stamps each, is supplied with 12 vanners, the other side also 30 heads, has nine vanners, or three to each 10 stamps. The pulp from the two heads of pneumatic stamps is led on to six vanners.

The richer grade ores, sometimes running as high as 15 per cent. of black tin per ton, are crushed on the side of the mill having the 12 vanners, two to each five stamps. The vanners are run at 192 revolutions per minute, and are spaced at 10 feet 6 inches, with a 6-foot passage way between their heads.

The main water service (3-inch and 4-inch galvanised piping) is brought over the passage way on the girders carrying the counter shafting, with 1-inch branches to each machine; similar branches are carried down at either end and in the middle of the shed, for washing down the floor, which is sloped ¼ inch to the foot from the centre of the passage way.

The vanners are set on sills, on pitch pine 10 inches deep and 8 inches wide. These were bedded in 2 inches to 3 inches of concrete, in order to make them bear all along their length, and to give a wider bearing on the ground, which was "made" under the outer row of machines.

A launder having two compartments, each 10 inches deep, is laid all around the vanner floor. The inner one catches the washings from the floor, and the outer one receives the overflow wash water from the belts. This launder is set perfectly level, so that the water can be drawn off at any point of the circuit.

The tailings launders are under the floor, and have a grade of ¾ inch to the foot. They empty into a cross launder, which takes the tailings to the classifier.

Wooden swing gates, which can be held in any position by a wedge, are put in the launders to regulate the amount of pulp to each machine, or if necessary to cut it off entirely from any machine during temporary stoppage.

The delivery from the launder to the distributor is by means of a 1½-inch hose, which has brass hose couplings at each end, screwed

firmly on to corresponding parts that are attached to the launder and distributor.

A short launder from the battery delivers the pulp on to a "grating" box (punched zinc screen) at the edge of the battery floor, to prevent "gravel" from getting on to the vanner belts.

Two men in each shift (four in all) attend to and regulate the vanners, in addition to which there are two men employed in repairing the machines. These six men per 24 hours attend to the whole of the concentration work as far as the vanners are concerned. There is a general foreman over the whole mill.

The concentrates are drawn and assayed every day. Samples of the tailings from the belts are taken every day, and after 24 hours are allowed for settling the water is decanted, and the sample assayed. The average value of the concentrates is 50 per cent. black tin per ton, the black tin containing 65 per cent. metallic tin.

A higher concentrate can be made, but it is found that the loss of fine tin in the tailings increases when making a higher grade concentrate.

About one ton of slime tin is produced per month from the settling boxes taking the overflow wash-water from the concentration troughs. This product is excessively fine.

The loss of tin in the tailings amounts on the average to 3 lbs. per ton of stuff.

The percentage of extraction thus shown on the vanners is a little over 94 of the gross contents, as ascertained by assays with the vanning shovel.

The concentrates from the vanners are calcined, and further treated by washing, in order to get a marketable product. Endeavours have been made to produce a concentrate that can be sold direct to the smelters without burning, but as yet unsuccessfully, as the concentrates contain too much fine waste and coarse sand, which reduces the parcel beyond the payable limit. This, however, may yet be worked out.

The cost of producing a concentrate containing about 25 per cent. black tin for calcining by the old method at this mill was 1s. 3d. per ton of stuff stamped. The cost of treatment by vanners, including all labour, steam, stores, maintenance (at the rate of 6½ per cent. per annum), interest on the capital expenditure (5 per cent. per annum), is under 6d. per ton.

The vanner produces a concentrate that contains twice as much black tin per ton as by the former system, the after treatment of which is in proportion reduced; and the total loss in the whole tailings, allowing for the former re-treatment of intermediate products, is doubtless less under the new system than with the old.

CHAPTER XVII.

TIN CRUSHING AND DRESSING MACHINERY.

THE old Cornish stamp is still in use in many of the mines in Cornwall, not because it is an effective machine, but the mines operating it are too poor to justify the cost of a more modern form of battery; it is an exceedingly interesting survival of the early days of crushing by machinery.

The stamp heads are 7 inches by 11 inches, and the mortar box has no bottom, a hard bottom being formed with the crushed ore being beaten into the ground.*

The chief feature to be urged in its favour is the low cost for maintenance and repairs. When the present machines are worn out, or the mines operating them are worked out, this machine will be relegated to the crushing appliances of the past.

The Californian type of stamp battery occupies in tin mining the same position as it does in gold mining, and supplies the means by which by far the largest quantity of tin ore is crushed.

There are various types of these machines on the market, which differ slightly in design and construction, and it is an easy matter to ascertain which particular design is best suited to the ore to be crushed.

In erecting a battery it is absolutely necessary to secure a good firm foundation; the following is the usual method employed:—The vertical mortar blocks are sunk in a pit to a depth of 6 to 10 feet, according to the position, and well packed all round with concrete. When the ground is unreliable horizontal foundations spread over a considerable area are necessary.

The framework of the battery can be either made of wood or iron, the advantage of using wood being that a certain amount of elasticity is obtained. Iron frames last longer, but the constant vibration has a tendency to loosen the bolts, thus causing trouble.

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* Latterly at Dolcoath bottoms similar to the Californian stamps have been put in, and increased the capacity of the mill by 29 per cent.

The mortar box is constructed of cast-iron and weighs about 2,400 lbs., a useful size being 4 feet high, 15 inches broad, and 4 feet 6 inches long, the bottom being 3 inches thick. Screens may be made of copper, iron, or sheet steel, and are fixed in frames about 3 inches above the top of the dies. For crushing tin ore usually a very fine screen is used, generally about 30 mesh.

The weight of the stamp depends on the ore to be crushed, but about 850 lbs. is found a useful general weight for crushing tin ore.

Pneumatic stamps are in use on the Dolcoath Mine in Cornwall, where they give very good results, but at present they have not come in for general use on account of the difficulty of repair and requiring skilled attendance for their successful operation. Extensive improvements are being made, and the general effectiveness of the stamp will be increased.

Huntington Mills have (in the author's experience) done excellent work on the reduction of soft dyke material carrying tin ore, but cannot be recommended for the crushing of the harder sorts of tin stones and capels.

The principle of the Huntington Mill is: the rolls are not fixed on parallel shafts pressed together by buffers, but suspended vertically, crushing by centrifugal force, which is brought into action when the frame on which they are hung is set in motion.

The chief advantages claimed are the saving in the cost of the machine, in the cost of transport and erection, and the rate of discharge.

There are various types of Ball Mills, but in the author's experience several machines that have been erected on tin mines have since been discarded for the battery.

The ore when crushed to pulp is variously handled. At the Mount Bischoff Mine it is first passed into double trough-rising classifiers, and then into two-compartment Hartz jiggers. All jigging machines take advantage of the law based on the fact that if two bodies of equal volume, but different specific gravity, are dropped simultaneously from the same height into water, the greater weight will settle on the bottom of the vessel or tank first.

This result is attained by the jigger through a series of rising and falling movements. The ore must be sized for successful jigging, from $\frac{1}{32}$ to $\frac{1}{4}$ of an inch in size. Ore that is too coarse requires too much power, and when it is too fine it has a tendency to pack.

The simplest form of jigger is an ordinary sieve having a perforated wire or metal bottom. This is shaken or jerked up and down by means of a frame and lever in a trough of water; the sand and gravel being thrown to the surface is removed by a scraper.

This form of machine is still employed on some of the Cornish mines, and is useful in prospecting operations.

The modern form is the automatic three-compartment jigger with a lever motion. The pulsation is got by the reciprocating action of the piston or plunger. The heavy ore passes into the bottom of the hutch in the jigger, from which it can be emptied through a plug valve into the receptacle below.

In Cornwall the majority of the mines pass the pulp directly on to Frue vanners and classify the tailings for subsequent slime treatment. In working this vanner care must be taken to ascertain by direct experiment on the ore to be treated, the relative amount of water and pulp to be supplied to the machine to get the best results; the exact speed and inclination required; all these points vary considerably with the ore that is concentrated.

The average inclination is from 3 to 5 inches in 12 feet. That can be increased if necessary to 10 inches or diminished to ½ an inch. The average speed of the belt is about 32 inches per minute.

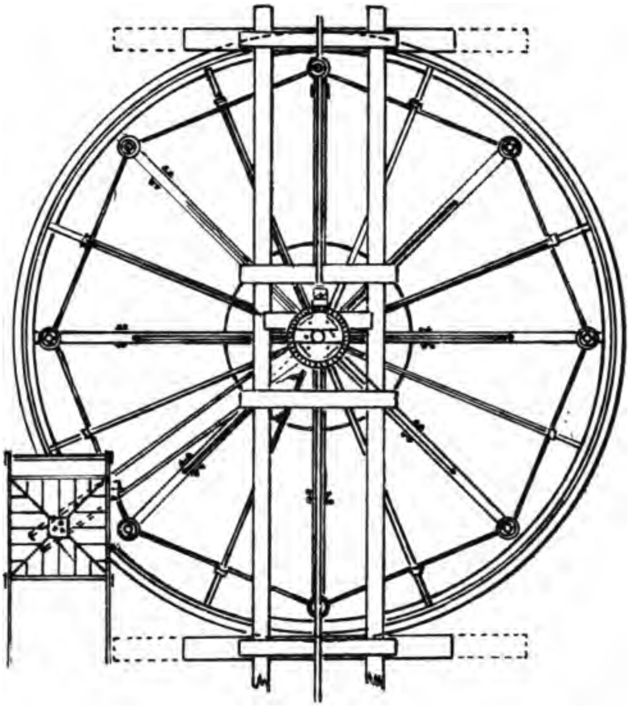
A good general plan in erecting a new machine is to set the frame with a fall of 4 inches in 12 feet, and run about a speed of 200 revolutions to the minute; be sure that a good supply of fresh water is readily available, run the machine for about an hour, and carefully examine the concentrates.

If a sticky bed is formed on the belt, increase the grade a little, but if there is no bed on a thin stream of pulp and water the grade should be flattened till the right consistency of pulp is obtained. Of the two extremes an insufficient bed is better than one that is too heavy and sticky. About three machines to every ten stamps will be found sufficient.

The WILFLEY TABLE is coming greatly into use in place of the buddle. This table should be started with but little pace towards the waste-discharge side, and a thin sheet of water should cover evenly the entire table, except that immediately below the feed opening. When the feed is turned on the table will then be entirely and evenly covered. It is important not to bow the surface of the table; and not to have any vibration arising from defective setting on the foundations. The fundamental idea of the table is to wash away any small particles of silica. From the time the pulp first reaches the table until the concentrates drop into the box, the silica on the surface of the pulp should be constantly washing towards the waste launder in a thin sheet of water.

When the concentrates begin to come off the end of the table, the side of the table is raised or lowered until the pulp separates at the lower tail corner, the concentrates going to the concentrates box, while the middlings pass into the middlings return trough; the springs should be run as loosely as possible. The movement is adjusted for a stroke of ¾ inch; this has been found usually to give the best results, and in no case should the stroke exceed 1 inch in length, nor should it be made shorter than ⅝ inch. The progressive motion given to the concentrates is accomplished by the short turn at the forward end of the stroke. By raising the adjustment block the turn is sharpened and the throw greater. In lowering the block the throw is shortened and the turn made less sharp.

Always allow ample time to elapse in which to note the results, as the entire bed of concentrates on the table is to be moved before a change becomes apparent. Assaying is the only sure method of determining the character of the work performed by the table.



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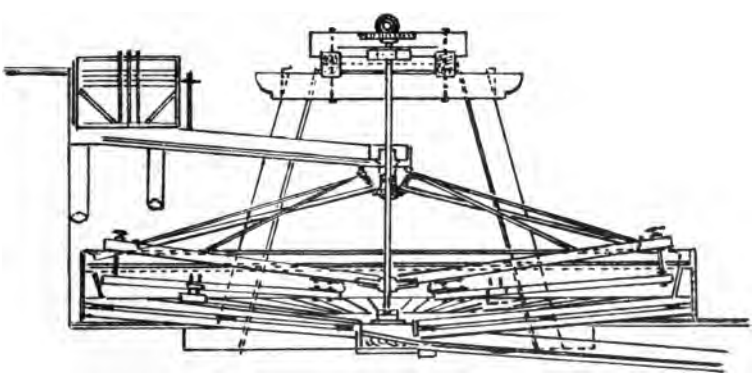


ELEVATION

FIG. 32.—CONCAVE BUDDLE.

The Buss Table.—The construction of this machine is simple, and the adjustment to suit the class of work required easy. The general precautions enumerated in the description of the previous concentrating machines apply equally to this.

From these various methods of concentrations the pulp passes to a system of convex and concave buddles. A great many mines in Cornwall still use the old round convex type of buddle, which is of extremely simple construction, the buddle being made in a circular pit made in the ground of about 22 feet in diameter and about 1½ deep. These buddles can be arranged so that the smaller ones treat the richer slimes and the larger ones the poorer.

The sides of the buddle pit are made of concrete or bricks. The floor of the buddle is set with an outward inclination of about 1 in 30. Smooth boards can be used, but concrete with a smooth surface of pure cement is better. A revolving head is fixed to a shaft and carries four arms, which distribute the slimes in an even layer. To each of the four arms is attached a board which carries a cloth or series of small brushes; these sweeping round, smooth out each successive layer of mineral as soon as formed. The number of revolutions vary according to the mineral treated, about four a minute being the usual rate of speed.

A small sluice gate in the outward rim carries away the waste overflow. Holes are made in the door of the sluice gate, which are plugged up as the layer of deposited mineral rises, till the deposit equals the height of the cone, and presents the appearance of a level surface. At this point the machine is stopped, rings are drawn round the various concentrates formed, the rich concentrates are taken out and re-buddled if necessary, or may be sent at once to the dolly tub.

The disadvantages of this type of machine are, first, no finished product can be made at once, and also all the handling must be done by hand labour, also the machine must remain idle during the process of clearing it up.

"Green's Vanning Table" for the concentration of slimes makes an excellent substitute for the old-fashioned buddle; it gives a clean, rich concentrate with no handling of poor middlings. The table has a flat surface fitted with longitudinal riffles of graduated length; and a motion is obtained resembling the action of vanning by hand.

The Concave Buddle.—The circumference here is higher than the centre where the discharge takes place. This buddle is generally used to enrich the heads from the round buddle. The slope given to the floor is about 1 in 12. The larger proportion of the ore is deposited near the circumference of the floor, almost immediately under the circular ledge; the waste waters flow over the top of the swing ring into a well and then into the settling pits.

There have been many new slime tables invented and used. The author saw a concentrating slime table in use on the Dolcoath Mine, known as the Acme combined concentrating table; the advantages

claimed for this form of table are as follows: 1st. The pulp by this frame is doubly treated automatically. 2nd. The frame requires little attention when once adjusted. 3rd. There are no middlings. 4th. It requires only half of a horse-power to drive it. 5th. Will make a cleaner and more valuable concentrate than other machines of a similar nature. On the whole this seems to be a fairly satisfactory machine, and certainly presents a few small improvements to the ordinary revolving slime table.

What is known as the revolving slime table is a circular conical table about 18 feet in diameter. The ore is fed on the outer edge in a small stream with water flowing down the incline to the inner edge, the heavier particles being deposited, which adhere to the table; the revolution of the table carries round the deposited material, which is subjected to the washing action of clear water flowing over it, and is eventually brushed and washed off the table, the clean concentrates dropping into launders placed below to receive them; the table thus continually arrives cleaned to receive the flow of pulp, being freed of waste, middlings, and clean concentrates before the full revolution is completed.

The surface is made of wood, carefully dressed—but in the author's opinion a far better wearing surface is obtained by cement, coated with a mixture of 25 per cent. turpentine and 75 per cent. coal tar, laid on with a brush, when the cement is sufficiently dry to absorb it. This face will keep in good working order for two years, whilst the wood has a tendency to work into grooves, and thus tin ore is lost.

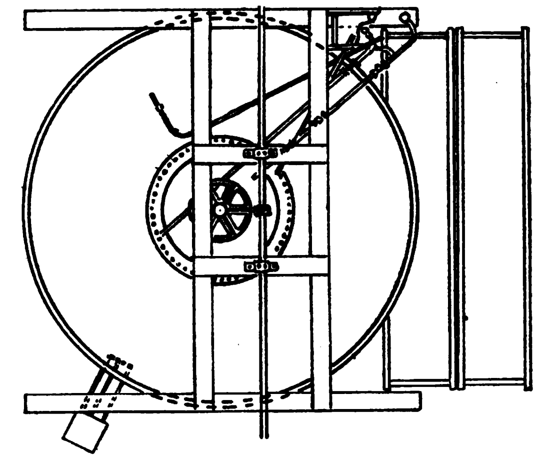
The Evans slime table is also used, and this machine can be kept constantly at work without loss of time in cleaning up. The pulp is delivered into the centre of the table, and the rich concentrates are washed off by a slow jet of clean water. It has capacity for treating about 25 tons a day of 24 hours. The chief disadvantage of this type of table is the difficulty in obtaining anything like a perfectly even motion. This trouble is largely overcome at Dolcoath by using a worm and pinion, the table being driven by an electric motor.

The Linkenbach table possesses many advantages; the initial cost is, however, very high, and it is not in general use on that account.

In order to obtain the highest extraction possible from the slimes it is necessary to re-grind a portion of the coarser material. Various machines have been used for this purpose. At the Mount Bischoff Tin Mine a Chilian mill is used for this purpose, but it is an inefficient grinding machine, and not so well suited as the improved tube mill or barrel pulverizer in use in Cornwall.

It is believed to be the earliest form of the present tube mill now so largely used in gold slime reductions.

It is an exceedingly simple machine to work. There are no screens, there being free exit for the ground pulp. It requires about 6 h.-p. to drive it. Scrap-iron or flints may be used in the barrel for grinding. A machine 4 feet in diameter, 12 feet long, has a grinding capacity of 15 tons every 24 hours, making 40 revolutions per minute.



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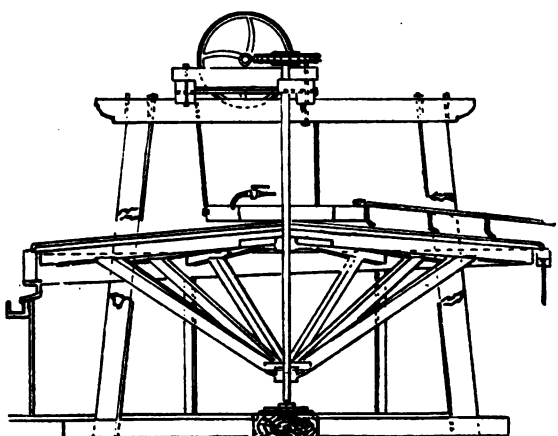

ELEVATION

FIG. 33.—SLIME TABLE.

A subsequent treatment of the pulverized slimes is made over slime tables as described. Automatic rag frames and settling pits are then used, in order to concentrate the rich slimes and leave the waste as poor as possible; the operation may be profitably repeated several times, as tin ore is very difficult to separate from its gangues when in a fine state of division.

The separation of wolfram from tin ore has been in the past a problem of considerable moment to the tin dresser; but thanks to the development of the magnetic separator, what was once a source of loss and trouble has been turned into a product of considerable value.

In magnetic dressing there is no universal machine that can be used for all purposes, and the separation of wolfram from tin ore can be effected by either a dry or wet separation. The machine that has been used with success in Cornwall in the Clitters and other tin mines is the Wetherill separator, cross-band type (1. C. 4.), the best type for the separation of wolfram from tin.

This machine takes about 1½ h.-p., and makes a remarkably clean separation. It is of simple construction and easily manipulated.

In considering the most successful methods of modern tin-dressing, the best known systems are those in which, first, tin-dressing with classification and the use of some form of concentrating table; second, tin-dressing is carried on without classification, by means of Frue vanners.

Unless two small testing plants could be arranged so as to run side by side, treating the same class of ore, with the object of proving the relative value of these two systems, it will be impossible to settle definitely this vexed question.

But in the writer's opinion, the better system is that of first classifying as closely as possible by means of up-current classifiers, so as to carry off the finer slimes, and to leave the coarser product to be treated by impact screens, before passing on to some form of concentrating table like the Wilfley, Buss, or Green. The resulting products from the tables are: first, a clean concentrate; secondly, a middle product; and, thirdly, waste.

I do not believe in returning this middle product on to the table. From careful microscopic examinations of this middle product, it is shown that the majority of the tin in it, is adhering to very small particles of gangue, and it is necessary, in order to recover the cassiterite, to pulverise this middle product, and no amount of returning to the table without re-grinding will effect any considerable saving. This middle product should be run direct into some form of pulveriser, like the ordinary tube or ball mill. For this system the Frue vanner is impracticable, for although the concentrate is clean, there is no middle product, while the so-called waste contains a considerable percentage of tin, which necessitates a further handling of the whole of the tailings, in order to recover the tin; and generally the series of operations dealing with these tailings commences with some form of classifier.

The only case where it might be better to instal Frue vanners is in a small mine where first cost is a matter of great consideration, and where fine working is not a matter of moment.

After the preliminary treatment in either of these systems comes the the great question of the successful recovery of tin slimes. The product from the classifiers, as well as pulverisers, flows into spitzlutten, and here the slimes and fine sands are readily separable from each other. Another way is to allow the products to flow into a modified form of slime pits, used alternately, with an outlet at the lower end which can be progressively closed by a series of stops. The following is the general method of procedure :—To fill the pit the stops are taken out, and the stream of fine sand and slime accumulates in the upper end ; the fine sands settle readily, while the slimes flow continuously either direct on to slime tables, or first over dead frames into small pits, before passing over the slime tables. As these sands begin to accumulate in the pit, the stops are put in at the lower end. These do not interfere with the outflow of the slimes, but merely assist at keeping back the sands in the pit until full. These sands can be readily concentrated on some form of slime-treating table. In my opinion, a Speery vanner is an excellent machine for this purpose ; but no difficulty will be experienced if the ordinary buddle form of concentration is used.

It would be as well at this point to try and arrive, if possible, at a working definition of what slime really is. It is the common practice among miners to class everything that passes through a 150-mesh screen as slime, but that hardly conveys the right impression of the form of slime that gives trouble to the tin dresser. It might be defined as follows :—"When the slime remains suspended in clear water for a perceptible time, or that it will sink at an average given rate of one inch in twelve seconds, and that when rubbed between the fingers no grittiness is felt." The measurement of these particles is a practical impossibility, as they would require to be measured to the ten-thousandth part of an inch. It is also quite true that the water with this form of slime in suspension, will also carry away the fine sands ; but as I have already explained, these sands do not present the difficulty.

From my experience in Cornwall, the question of the treatment of these fine slimes has not received the attention that it merits, and the only place where this problem has been tackled on a large scale is at the Mount-Bischoff Mine in Tasmania. Here they have a very extensive series of slime pits, where the slimes are given space and time to settle, both being necessary to effect a complete precipitation.

At the Clitters Mine, of which a description is given, this form of slime is not treated ; and in the Camborne District its recovery is undertaken by separate tin stream companies on the Red River with more or less success.

Another question over which there has been a controversy is the question of a graduated form of crushing. There are mines that can be successfully worked by fine crushing ; but I think there is little doubt that if a hard ore is sufficiently pulverised to pass through a 40-mesh

screen that it will found to contain a considerable percentage of very fine slimes ; whereas, this same ore crushed through a 25-mesh and then classified and pulverized, the residue will be found to contain a far less percentage of slime.

Of course the question of first cost is a matter of serious importance, as it is considerably higher when the system of graduated crushing is adopted.

As these questions are still undecided, I have thought it better to give in this chapter a complete synopsis of both the systems, as I find that there are many capable engineers who hold strong views on both sides, and it is only by actual experience, or ascertained results on the particular ore to be treated, that a definite conclusion can be arrived at.

Where the loss on the average lode matter is only 3 lbs. to the ton, the tin dresser is justified in regarding his operations as successful.

The Treatment of Tin-Wolfram-Copper Ores at the Clitters United Mines.*

The new Clitters mill, as originally erected, was divided into two separate systems, one for the treatment of tin ores containing little wolfram, and one for tin ores containing a large percentage of wolfram ; but owing to the successful working of the magnetic separation the two systems have to great advantage since been merged into one.

The arrangement of the mill is now as follows : The greater part of the ore arrives at the back of the mill and passes over two grizzleys, whose bars are 2 inches apart, the fines falling directly into the large storage hopper, whilst the coarse pieces fall on the platform and from thence are fed into a 15 in. × 10 in. Blake-Marsden rock-breaker, and delivered also into the same storage hopper. The ore is then passed by four Challenge feeders into the boxes of four batteries, each of five stamps. The weight of each head is 800 lbs., and they are dropped ninety-five times per minute. The pulp is passed through No. 25-mesh gun-metal woven wire screening. The use of this material for the screening is necessary, as the ore at times contains a considerable amount of free acid, and gun-metal screening was found to last almost twice as long as steel screening.

A smaller portion of the ore is dumped into a storage hopper, and is, after the elimination of its fines by the automatic shaking screen, fed into a small 12 in. × 8 in. rock-breaker. The ore then passes through a set of friction-driven rolls of 28 in. diam. × 12 in. face and hoisted by the elevator to the vibro screen, from whence the fines are sent to a No. 6 ball mill, which crushes them through No. 30-mesh

* Trans. Inst. Min. and Met. F. Dietzsch, 1905.

screening. The coarse material collecting on top of the vibro screen returns to the rolls and is re-crushed.

The combined pulp from the 25 stamps and the ball mill pass through three spitzlutten; two of these have three compartments of varying depths, and one has only two compartments. The product of each spitzlutten passes to a Buss swinging table, while the overflow of the three spitzlutten (fines) goes to a ten-compartment condensing and classifying spitzkasten, 50 feet long by 6 feet wide on top, and 5 feet 6 inches deep. Three pairs of these spitzkasten compartments supply their pulp through launders to three two-compartment distributing boxes, which in turn feed three double Lührig vanners.

The remaining four spitzkasten compartments supply a double vanner through a single two-compartment distributing box. The overflow at the end of the series of spitzkasten, together with the tailings from the Buss tables, the overflow of the distributing boxes, and the tailings of the Lührig vanners outside of the mill, pass into a second eight-compartment condensing spitzkasten 40 feet long, 6 feet wide on top, and 5 feet 6 inches deep. While passing through the last-mentioned spitzkasten, a small quantity of lime in solution is added, which clarifies the water sufficiently to enable it to be pumped back by a centrifugal pump to a water tank and used again in the battery.

The Buss swinging tables, to which reference has been made, are eight in number, and the heads from these pass forward as witts to the calciner, whilst the middlings are at present returned to the tables by elevator wheels, one of which is attached to each table. The tailings, that form a large proportion of the whole pulp charge, go direct to the waste heaps. Experience has shown that the return of the middlings to the table is not the correct procedure, as a large proportion of coarser particles tend to circulate continually, unless they are cut off by means of a piece of wire screening.

In future it is intended to collect the middlings from the tables and to re-crush them in a wet ball mill, that is at present being used to re-crush a stock of high-grade middlings, which had accumulated in the past. After re-crushing, the table middlings, together with the overflow of the spitzlutten, will be treated on the Lührig vanners. At the same time, by using a No. 20-mesh screen, the first crushing of the ore will be made much coarser, and so decrease the production of slimes and increase the tonnage treated. It may here be remarked that the ball mill has been found to slime very much less than the stamp mill, and that even after re-crushing in a ball mill through an 80-mesh the production of slimes was found to be comparatively small. It follows that whilst the tables finally eliminate a very large proportion of the light waste in one operation, and only allow waste particles carrying some minerals to be caught as middlings, the quantity of these latter is by no means large, and can be easily dealt with in a small ball mill, so that as a net result not only is the advantage of not sliming the ore attained in the first instance, but the capacity of the mill is greatly increased by this form of graduated crushing.

Each of the five distributing boxes in front of the Lührig vanners has two compartments, each of which supplies one-half of a double vanner. Four of these boxes take the original pulp from the large spitzkasten, whilst the fifth takes the middlings from the other four vanners, so as to allow of a separate re-treatment of the middlings. The middlings from the vanners are collected and pumped by a centrifugal pump to a small condensing spitzkasten to remove the surplus water, and the bottom discharge of this spitzkasten passes to a distributing box from which each compartment feeds one-half of a double vanner. Formerly these middlings were allowed to mix again with the general pulp without being re-classified, but as a large proportion of them was found to circulate without being further concentrated, they are now practically treated on separate vanners under appropriate conditions for their concentration. The heads from the vanners are a high-grade concentrate, and go to the calciner, where they are roasted separately from the coarser concentrates of the Buss tables. This arrangement has been found to save some re-classifying of the roasted concentrates, and secures a better market for the coarse products.

The concentrates from the Buss tables are usually free from any siliceous waste, and contain only the sulphides of iron, copper, and arsenic, the oxides of tin and wolframite. They are of a very much higher grade of concentration than the average Cornish concentrates called "witts," and are separately roasted and then electro-magnetically treated. The vanner concentrates, which contain much of the iron oxides originally in the ore, are of lower grade as compared with those from the Buss tables, and are therefore, prior to their electro-magnetic treatment, re-classified and enriched in ordinary convex Cornish buddles, in which the bulk of the iron oxides are removed and go to waste.

The magnetic separator used at Clitters is the Wetherill machine known by the makers as the "cross-belt type." It consists of a wooden frame carrying two pairs of electro-magnets in juxtaposition. Two magnets are beneath the main conveying-belt and two above, and the winding is arranged in such a manner that the north pole of one magnet is opposite the south pole of the other. The poles of the lower magnets are flat, while those of the upper magnets are pointed. In this way four long, narrow, and highly concentrated fields are formed, through which the main endless conveying belt passes. The ore is placed in a hopper, and by a distributor is evenly spread on the main conveying-belt. As soon as the ore enters the magnetic field the magnetic portions fly to the upper poles, which, being pointed in shape, have a greater attractive power than the flat lower poles. The lines of magnetic force converge to the pointed poles, thus making the field in their proximity more concentrated. Smaller endless carrying belts pass underneath the upper pointed poles, *i.e.* between the main conveying belt (with its charge of mineral) and the poles, and these small belts run in a direction at right angles to that in which the main conveying belt moves.

The magnetic particles flying towards the upper poles are intercepted by the small carrying belts, and by adhering to the lower surface are carried sideways out of the magnetic field, so that they cease to adhere to the belts and drop by gravity into separate receptacles. The distances between the upper and lower poles can be regulated by set screws, and in this manner the intensity of the field can be either increased or decreased.

The intensity of the field can be further regulated to a nicer degree by means of a rheostat, which regulates the current round each pair of magnets. The first pair of magnets are arranged so as to give a weaker field than the second pair, and in this way the strongly magnetic particles are removed during the passage through the first two fields, whilst the weakly magnetic substances are removed in the last two fields.

The first field removes the greater portion of the magnetic oxide of iron, and the product from the second field consists principally of the other oxides of iron with oxides of copper adhering. The third field yields some more oxides of iron mixed with wolframite, and the fourth field produces fairly clean wolframite. The non-magnetic product falling off the end of the main conveying belt consists of the oxides of tin and any siliceous waste that may have escaped elimination in the wet-dressing operations.

The product from the first magnetic field, provided that the field be kept sufficiently weak, is generally sufficiently poor in tin, wolfram, and copper to be allowed to go to waste. That of the second field, if sufficiently free from tin and wolfram, is sold to the copper smelter and fetches a good price, owing to the high percentage of the oxides of iron present. It also frequently contains up to 10% of copper.

Sometimes the products from the first and second magnetic fields have too much tin and wolfram adhering to the oxides of iron and copper to admit of the usual course being followed. If this is the case these products are re-treated after having been further crushed in the dry state in the No. 2 ball mill. This is only done after a sufficient quantity has been allowed to accumulate to make it expedient to dry the ball mill for that purpose; for these products, having once been roasted, will contain too much acid to be crushed with impunity in the wet way.

The coarse products from the table concentrates obtained from the third and fourth fields, consisting of wolframite mixed with some oxides of iron, are usually clean enough to be finished in tossing-kieves.

The fine-grained products from the vanner concentrates obtained from the third and fourth magnetic fields are first buddled and then finished in kieves. The non-magnetic product is usually sufficiently clean to be simply tossed in a kieve to make it marketable as tin oxide.

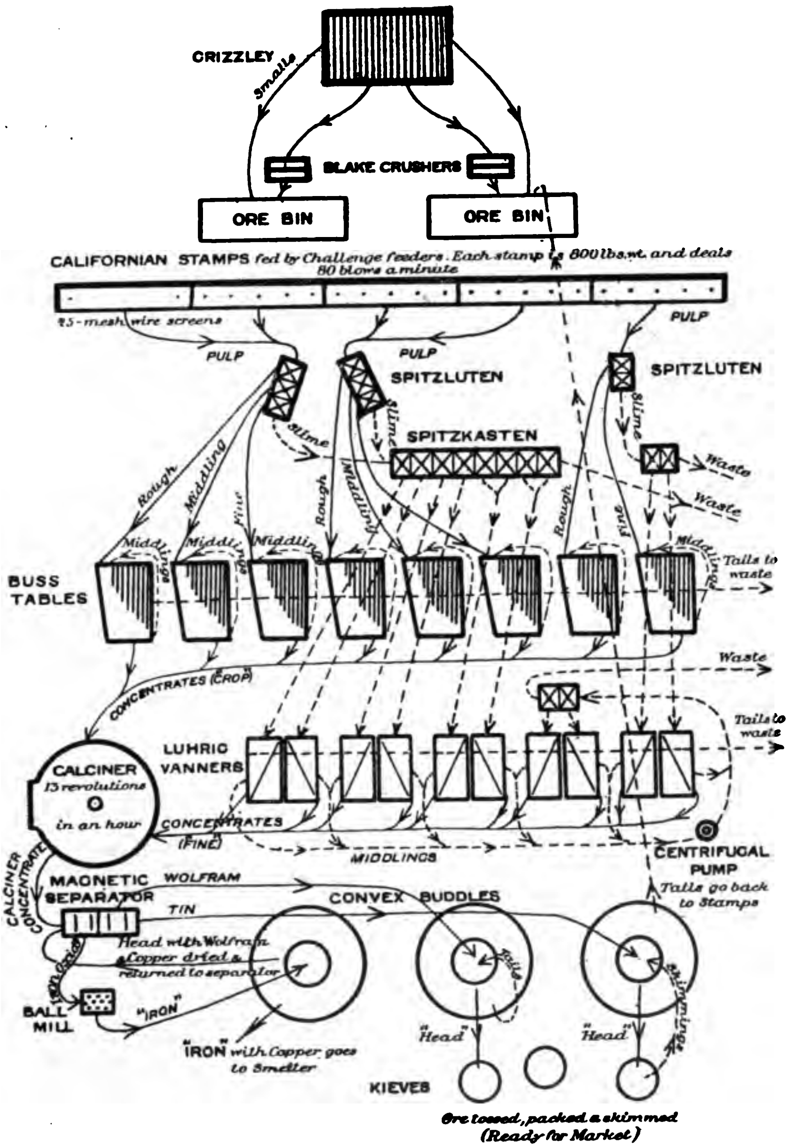

Fig. 34.—ORE-DRESSING PLANT OF THE GUNNISLAKE CLITTERS MINE.
(D. A. MACALISTER.)

Clitters United Mines.

Details of Milling and Dressing Costs for month of June, 1903.
No. of Stamps, 25. No. of days, 26. Tons crushed, 2,540.

	Mill Cost.		Total Cost.	@ per Ton.
		s. d.	£ s. d.	d.
2-12 hr. shifts	2 Engine Drivers @ 4/2 per shift	216 8	19 10 0	1·84
" "	2 Stokers @ 3/4 per shift	173 4		
" "	2 Shift Foremen @ 6/- per shift	312 0	73 9 0	6·94
3- 8 hr. shift ...	3 Stamp-men @ 3/4 per shift	260 0		
2-12 " ...	2 Table Floor men @ 3/4 per shift ...	173 4		
" " ...	2 Vanner Floor men @ 3/4 per shift ...	173 4		
days only 10 hr. shift ...	3 General Helpers @ 3/4 per shift	260 0		
Do.	1 General Helper @ 2/- per shift	52 0		
Do.	1 each Fitter and Smith @ 5/- & 4/2 per shift	238 4		
	108 Tons of Coal @ 17/- per ton	...	91 16 0	8·67
	Shoes and Dies ...	...	25 0 0	2·36
	Screening Bronze Wire (gun-metal in use now)	...	5 0 0	0·47
	Belting, Feeder Spares, bearings, etc. ...	...	12 0 0	1·13
	Oil	...	5 15 0	0·54
	Waste, rivets, files and sundries	...	1 15 11	0·17
Total Mill Costs ...		...	£234 5 11	1/10·12
Calciner.				
2 Shift-men @ 3/4 + overtime Sundays		196 8	9 16 8	0·93
12 Tons of Coal @ 17/-		204 0	10 4 0	0·96
Magnetic Separator.				
2 Shift-men at 3/4 + overtime		...	9 16 8	0·93
Buddle Floors.				
3 Men and 18 Boys		...	45 6 2	4·28
Pumping.				
2 Shift-men @ 3/4 per shift + overtime for cleansing		...	10 4 9	3·38
30 Tons Coal @ 17/-		...	25 10 0	
Total Milling and Dressing Costs ...		...	£345 4 2	2/8·60

The existing system of tin dressing in Cornwall can only be defended on the ground of being established, and involving expense to change to a better. Experiments have been made with a view of determining a better process by the adoption of modern machinery. In any comparison of the existing and a proposed system, the following factors have to be considered :—

1. The relative costs of operating.
2. The relative losses in metal.
3. The relative commercial value of the product or "headings."

Proper values have to be attached to each of these factors in a final decision. It does not follow that the cheapest process to operate is necessarily the best, since the loss in tailings or an increased cost of treating products may more than neutralise the apparent advantage. Neither does the smallest loss in tailings of itself indicate the best process commercially, since it may involve higher cost of operating and higher cost or losses in realising the products. It is, therefore, obvious that any choice of methods must rest on a consideration of all three of the factors named.

A.—Single Treatment without Classification.*

This method involving the smallest amount of machinery and least attention would naturally commend itself for a first trial; but it seems probable, from the richness of much of the ore stamped, and the extreme fineness of the tin in the battery pulp, that losses will be too high to make it advisable to adopt so simple a treatment. There is no doubt that with a proper number of vanners and avoidance of excess of battery water, with steady speed of line shaft, and proper attendance, very close work can be done on the average ore as crushed, and a good clean product be obtained with comparatively poor tailings. It is, however, so easy to insure somewhat better results and diminished loss by a re-treatment, that it does not seem desirable to stop at the first step of improvement over existing methods.

B.—Single Treatment with Classification.*

The question of classification is a much debated one, and chiefly because circumstances alter cases so much. Those who hold that classification is essential to close concentration have certainly not had an opportunity of studying all the facts under varying conditions of working.

Now the general custom is established to put the unsized pulp direct on the Frue vanners, a custom thoroughly justified by the very close and excellent concentration hereby resulting. There is no upsetting of established laws in this on examination ; but the results depend on

* These notes were given to the author by Messrs. Fraser and Chalmers as the result of an exhaustive series of experiments carried out on the Dolcoath tin mine.

Photo by] FRUE VANNER SHED, DOLCOATH TIN MINE. [*Burrows, Camborne.*

a complicated series of elements, some of which are overlooked by those who lay down fixed rules. Some of these elements may be referred to.

The argument for classification rests broadly on the fact that an ore crushed through, say, a 40-mesh screen consists of all sizes of particles (from what will just pass the holes down to impalpable dust or slime), and that the largest sized grains of waste-rock cannot be washed away from the finest particles of mineral without excessive loss of the latter. The broad fact is true, but only under certain conditions is it as important as it seems. On a fixed surface, or on a slowly revolving surface (as in buddles), or on a bumping surface like a Rittinger table or Bilharz table, the difference in sizes of particles tends to neutralise differences of specific gravity, and the conditions of working so as to get off the larger particles of waste rock are unfavourable to the close saving of slime mineral. On a rapidly shaking (not bumping) surface, the conditions are not so unfavourable, as the larger particles do not rest on the surface owing to its rapid motion, but remain, as it were, suspended in the water, and can be moved down in its current with much less force than in the previous cases. That this is no mere theory is shown at once by the simple fact that a sixpence put flat on any buddle or bumping table would pass at once into the headings, while it will not do so on a Frue vanner, where it is unable to pass the washing water jets. This indicates a difference in the conditions of working in the two types of machines.

Some of the points in practice which become at times disadvantageous in connection with classification are these:—The introduction of clear water in the sizing boxes makes the overflowing fine slimes far too thin for effective work on vanners, unless large pointed settling boxes are again used to thicken the pulp by getting rid of excess water. The slime mineral which constitutes the chief loss on the vanner or other concentrator is that which goes off in the overflow from sizers. The vanner will not do close work if a large quantity of water runs on it; the pulp flows down too rapidly to allow of the fine mineral settling on the belt and so being saved. Of course, if this overflow from sizers carrying the most difficult mineral to save is run off to waste, or settled as a separate product, or treated on other machines, the vanners which take the coarser sizes of pulp appear to be doing better work because they are relieved of much of the slime mineral, and their tailings are cleaner; but in order to compare results with and without classification the proportional value of the overflow pulp must be added to that of the vanner tailings, for comparison with the average tailings value when the whole pulp unsized is put over the machines. Again, it is established that the vanner does excellent work on unsized pulp (not coarser than 40-mesh), and that much of the very finest slime mineral is saved when so operating; that is, some of the concentrates are just as fine as most of the slime mineral which constitutes the loss. The very finest slime mineral will save on a Frue vanner if it settles on the belt in flowing down its length, and what has failed to so settle and be saved can to a great extent be caught by running over a second machine. From this it follows that the loss of fine mineral from an

unsized pulp is not a necessary loss due to special difficulty in saving that particular mineral, but is largely what may be called an accidental loss ; the mineral has not happened to settle to the belt. A flood of water lessens the chance of the settling, and increases the loss of fine mineral in the tailings. When an unsized pulp is fed on the vanner a bed of the coarser sizes is formed, and the water and fine slimes filter and work down comparatively slowly through this bed, and not in uninterrupted waves, as when fine slimes alone are fed on. It follows from this that the fine slimes do actually, with an unsized pulp, have rather a better chance of depositing the finest mineral on the belt during the slow passage down the belt with the vanning or settling motion imparted. To get good work out of fine slimes alone on a vanner, not only must there be no excess of water, but it follows the capacity of the machine becomes very small. The argument from the above is that in many cases the proper method of increasing the effectiveness is not by classification, but by double treatment ; that the separation of the greater part of both coarse and fine mineral can be satisfactorily effected on unsized pulp, and that the portion difficult to save is not rendered more amenable by separation, but rather the process is in a measure complicated by the introduction of excess of water. It may be urged, and justly, that as the loss of mineral in the tailings is practically all in the slimes, it seems unnecessary to re-treat the whole mass of material. A most effective compromise of the pros. and cons. of classification is here indicated. A simple and economically working arrangement of vanners direct on unsized pulp will effect a very high saving of mineral as compared with any other form of machine, and deliver good clean concentrates, without the disadvantage of excess of water from classification. The loss in the tailings can be mostly separated as an overflow from a classifier, and will make a small proportion of the original to be re-treated on other vanners after pointed boxes, or on revolving buddles. The slime mineral by this means gets a double chance of being saved instead of a single one, as when it is separated in sizers and treated by itself on a vanner or other machine, it is a good principle to catch the fine mineral as far as possible at once instead of first drowning it with water.

C.—Double Treatment on Two Sets of Vanners.

This has been already referred to in general terms. It may be repeated that the loss in the tailings of a vanner on most ores is in a form quite susceptible of being reduced by treatment on a second machine. The vanner differs from all other concentrators in practice in this, that it is expected to treat the most difficult ores in one operation, making clean headings without any middling product to be re-worked. The very excellence of its work seems to have precluded the idea, in most cases, of using it twice over. Owing to the bad effect of excess of water, the best results are not obtained if the tailings of a 4-feet machine are put over another of the same size, because the clear wash water of the first machine has diluted too much the pulp for

successful working on the same width of belt again; *i.e.*, having more water, it needs to be spread out over a greater width to prevent too rapid a current. From this it follows that the tailings of a 4-feet belt should pass to a 6-feet belt, or, better still, to two 4-feet belts. Of course, if ample pointed box capacity be introduced between the two sets of machines, the necessity for increased belt area is not established; but if the first machines are followed by a second set to reduce losses, very close work is not so essential on the former, and they can be somewhat crowded as to capacity, making it then advisable to treat more slowly for the finest mineral on the second row.

D.—Single Treatment by Vanners, with Re-treatment of the Slimes from Tailings on Revolving Buddles after Classification.

By sizing the tailings of a single set of vanners, treating direct the unsized battery pulp, it will be found that the slime portion will show on vanning, by the shovel, a very perceptible head of tin. This slime portion is practically a concentrated product of the average tailings, containing as it does a large proportion of the whole of the tin escaping the vanners. Being free of the coarser portion of the original pulp, it is in a condition favourable for treatment on revolving buddles, which are not so unfavourably affected by excess of water as the vanners, owing to greater area. It may, therefore, be urged that, as either settling boxes to get rid of excess of water must be used, or a relatively large number of vanners be employed to handle the thin pulp, it is better to employ a cheap machine like the revolving buddle, even with its attendant disadvantage of middlings product. It is, of course, no reflection on the work of the vanner that it should be followed by another class of machine, as it is quite certain that if buddles were used first, the vanner would show a large yield from their tailings and middlings products. The question is merely one of expediency as to handling a sized and partially concentrated portion of tailings. For the first treatment of the pulp there can be no question as to the advantages of the vanner over any form of buddle. Even on the special tailings product it is probable that, by a thickening of pulp or division over a sufficient number of machines, the vanners would make cleaner headings with less loss in final tailings than two rows of revolving buddles, the lower treating the middlings of the upper; but with either arrangement the loss will be so small that it can safely be ignored when considered as tonnage on the original ore crushed.

An advantage connected with the sizing of the vanner tailings is that a special size of the coarsest particles of the crushed ore can be delivered as a product for re-grinding in pulverizers, if found to contain by assay sufficient metal to justify further reduction in size to liberate it. This re-ground product would be elevated and pass continuously over one or more special vanners added to the first row of machines; and the tailings of these join the general vanner tailings for classification before the buddles, or second set of vanners. In this way the

whole plant would be continuous-working and automatic, requiring the minimum of labour and attention, and giving high-grade concentrates at every point.

The Relative Commercial Value of the Product or "Headings."

At the present time the headings of the various dressing departments are calcined and then re-dressed. There is no necessity for calcining except to bring up the grade of product sent to smelter, and to diminish smelting charges by getting rid of sulphur and arsenic compounds present. On the contrary, there is a very decided objection to the cost of calcining; and equally to the labour and loss of tin in re-dressing the calcined material.

The products from the old fixed buddles are certainly not as clean as the concentrations would be from a system of modern dressing as already outlined, and an economy is here certain in the final process. It is absolutely certain that the cost alone of calcining would be a margin saved as against a somewhat increased cost of smelting; and even assuming that smelters would themselves calcine such a product before smelting, the question of relative cost would simply be as between doing this at the mine or at the smelter's. If still done at the mine there would at least be no increase over existing cost, and the question of re-dressing can therefore be independently considered. The re-dressing of the calcined headings involves an unavoidable loss of tin. After the greatest care in trying to save all the slime tin possible, it is now again put in water and over a variety of machines, handled and re-handled with a positive loss of a percentage of what has already with great trouble been obtained. The cost of this re-dressing has also to be considered; and when this cost is added to the direct loss, there is clearly a very good margin of profit to set against a little increased cost of smelting. In considering this modification it must not be forgotten that, when applied to really clean concentrates, such as it is proposed to make in the first place, the result is very different indeed to what it would be to compare simply costs of smelting present "headings" raw as against present calcined and re-dressed mineral.

In the discussion on the paper read by Mr. Sydney Fawns, "Notes on the Mount Bischoff Tin Mine," Mr. H. M. Morgans contributed the following remarks to the Institution of Mining and Metallurgy, 19th January, 1905:—

"Referring further to my offer at the last meeting, I have now obtained permission from Mr. R. Arthur Thomas, the manager of Dolcoath Mine, and from Mr. A. Mount-Haes, the Humboldt Company's representative, to make use of the results of the tests which the latter company carried out on about 9½ tons of Dolcoath ore. I have no information as to the part of the mine from which the ore came, but it is probable that for such a test the ore chosen was of ordinary average quality, representing a fair sample of the mine produce.

"The accompanying diagram shows, in perhaps the most concise way, the operations through which the ore passed. The percentage weights

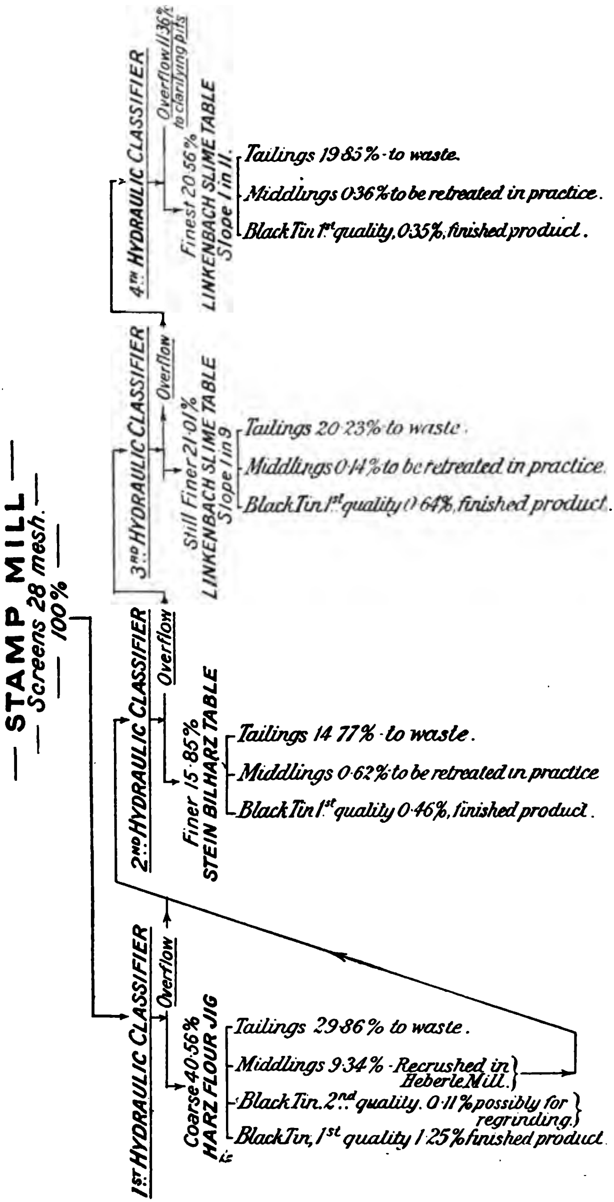

FIG. 35.—TEST WORKING OF DOLCOATH ORE BY THE HUMBOLDT COMPANY.

given refer to the total dry weight of crude ore. The diagram is self-explanatory, and the only comments I will make on it are, first, that the screens of the stamp mill were no finer than 28-mesh, after which the proportion of ore which needed further crushing in order to obtain a good extraction was about 10·5 %; and, second, that with this comparatively coarse crushing, 40·56 % of the crude ore was treated by simple jigging, 31·22 % being obtained from the jig as finished products, of which 1·25 % and 0·11 % were first and second quality black tin respectively, and 29·86 % were tailings.

"As regards the assay value of the various products, I give the following figures, which I understand were obtained by the process of vanning at Dolcoath. The Humboldt Company say of these figures that their chemical assays, of which I have no copy, agreed in the case of the concentrates, but differed in the cases of the crude ore and tailings, and they take no responsibility for the values :—

			Tin Oxide.
Crude ore - - -	100·00 %	- - - - -	2·00 %
1st quality concentrates	2·7 %	- average assay	80·00 %
2nd " "	0·11 %	- " "	48·5 %
Middlings - - -	1·21 %	(to be re-treated)	
Tailings - - about	96·00 %	- - trace to	0·3 %

"Obviously the concentrates are shown to contain more tin oxide than the crude ore. To clear up the mistake I am endeavouring to obtain the Humboldt Company's own assay results, but my remarks at the last meeting in reference to the fineness of Cornish ore are, I think, borne out by the figures given above, and are not seriously affected by the assay discrepancy."

CHAPTER XVIII.

DREDGING FOR TIN.

THE process of dredging for tin in different parts of the world is now so extensively practised, and so profitable, that it has reached the dignity of an industry. Before describing the various types of dredges at present in use, it may be as well to say a few words on prospecting alluvial tin-bearing deposits.

Whether or not a piece of ground is suitable for dredging is determined by physical conditions. The alluvial ore deposit must be of a considerable extent where the drainage area has been large. The best deposits are generally where the rivers have opened into flats; the payable ore must be disseminated over a wide area, as a considerable scope of ground is necessary for dredging operations. It is impossible to dredge profitably very narrow portions of a river, especially where there are large boulders. When the bedrock is hard, and the best wash is lying on that bedrock, the tin-recovery of the dredge is materially reduced. A piece of ground which fulfils the above conditions will bear investigation. Great care must be taken in prospecting, not only in the work itself, but also in placing the holes, and particularly in drawing conclusions from the results obtained. The author can cite a case which came under his notice on the Ringarooma River, Tasmania, where a dredge was erected without a proper investigation of the depth of wash and delivery of the tailings. The consequence was that when the dredge was put to work it was found to be totally unfitted for the task it had to perform, and the company lost all its capital; this, unfortunately, is only one out of many instances where want of careful investigation has resulted in loss.*

What might be termed an ideal dredging area would be one that could be successfully worked by the simplest class of plant, viz., the sluice box type of dredge, and which displays the following features:—

(1) A long length of area, free from rocky bars, and of fair width.

(2) A good water supply.

(3) A loose, shingle wash, free from cement or clay.

(4) The absence of large boulders or sunken timber.

(5) The bottom or bedrock being soft and easily worked by the buckets.

(6) The ground not being too deep, and all below water (an average of 20 ft. is a good dredging depth).

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* Trans. Inst. Min. and Met. E. S. and G. N. Marks, 1896.

It is considered better to find a little gold all through the material to be dredged, when examining an area, than to have it all on the bottom, as the former condition will give steadier yields.

As one seldom finds ideal areas, it is a question, when inspecting dredging ground, of deciding if it is possible to get over difficulties arising from poor facilities, or conditions, in the way of successful operations. In judging these matters no arbitrary rule can be laid down, but one must be guided largely by experience and knowledge of what a dredge can do.

A good-sized area is necessary to give sufficient life to the enterprise, as under favourable circumstances, with a dredge of 4½ cub. ft. bucket capacity, on the average, an acre a month would be worked; this, of course, depending on the depth to bedrock and the class of material to be treated.

Bars of rocks across an area to be dredged, and over which the dredge must pass, are not uncommon. When this is the case, there must be facilities for dam building in order to float the dredge over the obstacle. If the expense is not too great, blasting may at times be resorted to.

To do good work, a dredge requires a wide face to operate upon; narrow ground necessitates much shifting of lines, and entails loss of time through having to take out corners. A dredge cannot work in a paddock narrower than its length, as there must be sufficient room to allow it to swing right round.

The depth of ground above and below water-level, and the class of material that has to be lifted, must be considered, as the design of plant depends largely on these factors.

As a general statement dredging ground can be classed as that in which one finds, first, from grass roots to bedrock, one mass of stony gravel wash, and second, a layer of wash on the bottom over which may lie sand, or very light drift, or alternate beds of clay, sand, black soil, loam, etc.

In the first case, when one only has a gravel or wash to deal with, if the bedrock is soft and there is an efficient water supply available, the proposition offers no difficulties; but when there are other materials to be dealt with such as are above enumerated, it becomes a matter of study as to whether they can be successfully handled.

The objection to dealing with clay in thick beds is, that it is very slow working when the buckets are filled with it; it is frequently found that they will revolve without emptying, and when they do empty, it is in compact, bucket-shaped masses, which are apt to pile up on the drop plate, where there is not sufficient water to carry them away, and the buckets have to be stopped, the accumulation cut up by hand, and washed away in small pieces.

A clayey adhesive wash is detrimental for the reason that there is not time for it to be washed clean and the tin liberated, either by treatment in a sluice run or revolving screen. Such classes of wash require puddling, a process too slow for the treatment of the quantity of material raised by a dredge. However, ground containing clayey

wash and clay over-burden is made to pay where it is rich in tin ore, but the percentage won is small.

Bands of cement of any thickness are practically prohibitive for dredging, although we have experience of one case where a dredge worked ground 35 ft. deep in which there was a band of very hard cement lying some distance below the surface, with free wash above and below it. The wash was dredged below the cement, which remained protruding from the face, after which the ladder was raised and the buckets kept tearing at the cement, and in time it was broken up, but at great cost of wear and tear, as buckets were destroyed continually and links and pins broken. The area was, we believe, rich, but it is very doubtful if this class of ground paid to work. Figures of working costs are not obtainable, and we are inclined to believe that all profit, over and above actual working expenses, would be absorbed by renewals to plant, which were frequent.

Sand occurring in thick beds is difficult at times to deal with, unless special means are adopted by the use of the sand elevator as described. This only applies to paddock dredging where the tailings have no get-away, as in the case of a river.

The presence of large boulders and loose masses of rocks do not necessarily hinder operations, unless they occur in nests or patches, under which circumstances the ground may be passed over without working the bottom, floating room only being taken by the dredge. Sunken logs and trees in the ground, if they do not occur in too great an abundance, are not a bar to successful operations, but then special means have to be provided for dealing with them in the shape of a mast and derrick for raising the logs. We have had to deal with trees 60 ft. in length, with 5 ft. butts, lying 15 to 20 ft. below the surface.

The bedrock or bottom on which the buckets work must be soft to insure best yields, for while the plant is at work the bulk of the tin puddles down, and if the buckets cannot scrape the bottom there is great loss.

In a country where the rivers and creeks are dry or nearly so in summer time, the question of obtaining sufficient water is often of moment. As can well be understood, the more water available the better, but it requires very little added water to keep going when a dredge paddock is full, sufficient only to replenish soakage through the drifts and loss by evaporation being necessary.

At times there is no available water running on an area, in which case a supply may be obtained from the surrounding country by gravitation. There are cases where a flat above a river level has been worked, the water supply being obtained by pumping. This was done by the author in one case, using a No. 7 pulsometer, pumping water up 20 ft. to the paddock. A supply of 120,000 gals. in the 24 hours was found sufficient.

Although one can work with a very limited supply of water, there is always the drawback that the water in the paddock becomes dirty and thick, and this may cause loss.

To determine dredging facilities, the foregoing conditions have been pointed out as a guide as to where difficulties may be found, but they may or may not, according to circumstances, be overcome, and the statements are not to be taken as conclusive in any case, without a practical test being made.

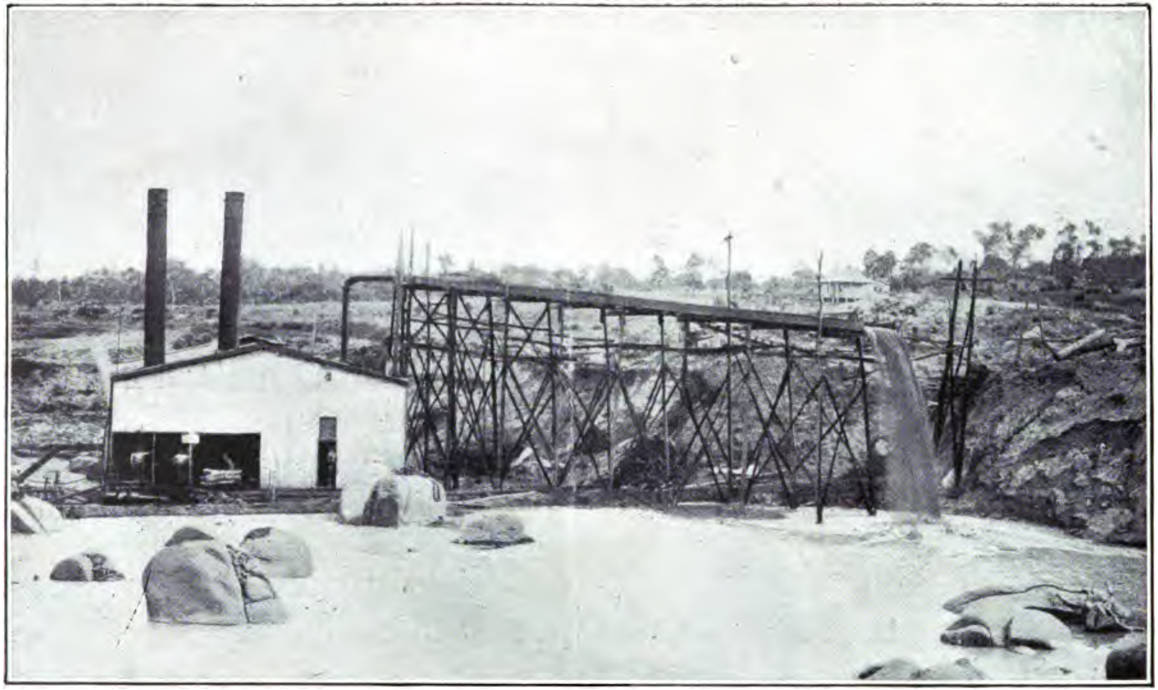
Having satisfied one's self that the local conditions and class of ground to be dredged are satisfactory, the matter of tin contents should then be studied and ascertained.

It is a difficult matter without going to great expense to get at the *actual average* value of dredging areas. One must be guided by experience in judging prospecting results before deciding to equip any area.

Prospecting work is generally done with a boring machine, which sinks a hole up to 6 inches in diameter. The test by a bore is nearly as accurate as the test by shaft so far as the values obtained from the gravel prospected is concerned; but careful expert judgment must be used to reach an approximately accurate conclusion from the result of either bore or shaft. The more holes sunk the nearer you come to the true value of a property. "My deduction from a great number of cases in actual practice," says Mr. W. A. Griffin, a well-known Californian authority on dredging, "is that a dredge will produce from 60 to 70 per cent. of the arithmetical average value shown by drill-holes when the holes are placed approximately 5 to each 10 acres of ground." But, in fact, it is much safer to bore at least one hole for every acre. A plan that has been adopted as the result of practical experience is as follows:—If the banks of a creek or river are being prospected, a line of holes are sunk from 80 to 100 ft. apart, this is found where done with a 5 in. auger to give a very fair average sample. The cost of this method of sampling, under ordinary conditions, runs out at about 1s. 6d. per foot, from three to four holes per 24 hours 10 ft. deep can be bored by skilled workmen. Dredging is carried on in the rivers as well as on the banks contiguous thereto. In paddock-dredging a spit is dug inland and the hull of the dredge is floated in it. Very little water is required to float the dredge, and a small clear running supply to work it, as the water which is pumped for washing purposes comes back to the pit. The amount of water is determined by the cleanness of the gravel. There are two factors which must not be overlooked in starting dredging operations, viz., transportation and power, for where these are high the average value of the property must be proportionately high. Finally, it must never be forgotten that the "essence of the contract" when prospecting for alluvial is to ascertain the exact depth of the wash and water-level with a view to estimating the distance and height that it will be necessary to deliver the tailings, and selecting the kind of machine most suitable for the class of country to be treated.

There may be said to be five types of dredges that can be used:—

(1) *The old Spoon or Dipper Dredge*, which at the best is an unsatisfactory machine, and not adapted for work on a large scale, being only useful for preliminary operations when prospecting. The chief objection to this dredge is that it deposits the material intermittently, and is both slow and costly in operation. However, as this machine



SUCTION DREDGE AT COPE'S CREEK, NEW SOUTH WALES.

has almost fallen into disuse, it is not necessary to say any more concerning it.

(2) *The Suction Type of Dredge.*—This lifts up by means of a large centrifugal pump the sands or gravels to be treated; it can also raise stones or small boulders provided they are within 2 inches of the diameter of the suction-pipe without interfering with the proper working of the pump or causing any injury to the same. The suction-pipe can also be raised or lowered as occasion requires; this makes the recovery of this type of dredge very effective, and enables it to work round large masses of rock which would prevent the effective action of the bucket type of dredge.

The mechanical drawback to the suction dredge is that a large proportion of the power is used in pumping water, the proportion of wash raised to water in height being relatively small, but the water raised can, however, be used for sluicing purposes.

The New Wylie Creek Dredging Co., N.S.W., is using a modern type of ladder bucket dredge, the construction of which cost about £7,000. The pontoon is 40 ft. in length and 20 ft. across. The machinery is driven by a 12-h.p. compound high pressure steam engine. There are 27 buckets used having a capacity of 4 cub. ft., the average depth of ground dredged is 20 ft. About 8,000 to 9,000 tons of alluvial drift is treated per 24 hours, from this some 7 cwt. of Tin Concentrates is saved, which when cleaned up give an almost fine sample of cassiterite worth 76% of metallic tin.

(3) *The Centrifugal Pump Dredge* operates in a somewhat similar way, except that the pontoon is resting on the bedrock, and the pump operates from a well into which the gravels are washed by means of hydraulic nozzles (from water supplied by small centrifugal pumps on the pontoon), first into small sluices from the faces which convey the gravels, and secondly into a main sluice leading to the well in which the pump operates. When it is necessary to move the dredge, water is let into the enclosure, and the dredge floated into the new position chosen and the operation repeated. The tin-ore is saved by means of a long sluice, as seen in the accompanying view of the Cope's Creek Company centrifugal pump dredge.

The following is the machinery required for a suction dredge fitted with hydraulic pumps and sluice boxes. The steam engine generally in use is a coupled compound surface condensing one, with high and low pressure cylinders working at a pressure of up to 150 lbs. to the square inch, the steam being supplied by suitable boilers, and the condenser has to be of sufficient capacity, so that the sluicing water can pass through the tubes, thus avoiding the necessity for a circulating pump. The pontoon is always built of well-seasoned timber, the joints thoroughly calked, and the whole covered with two coats of tar. A house is built all over this pontoon. The gravel pump to raise the material is a large centrifugal pump, of which there are several patent ones in the market differing slightly in construction. It has a very strong outer case of cast iron. The pump shaft bearing is fitted with adjustable gun-metal steps, and it is necessary to provide

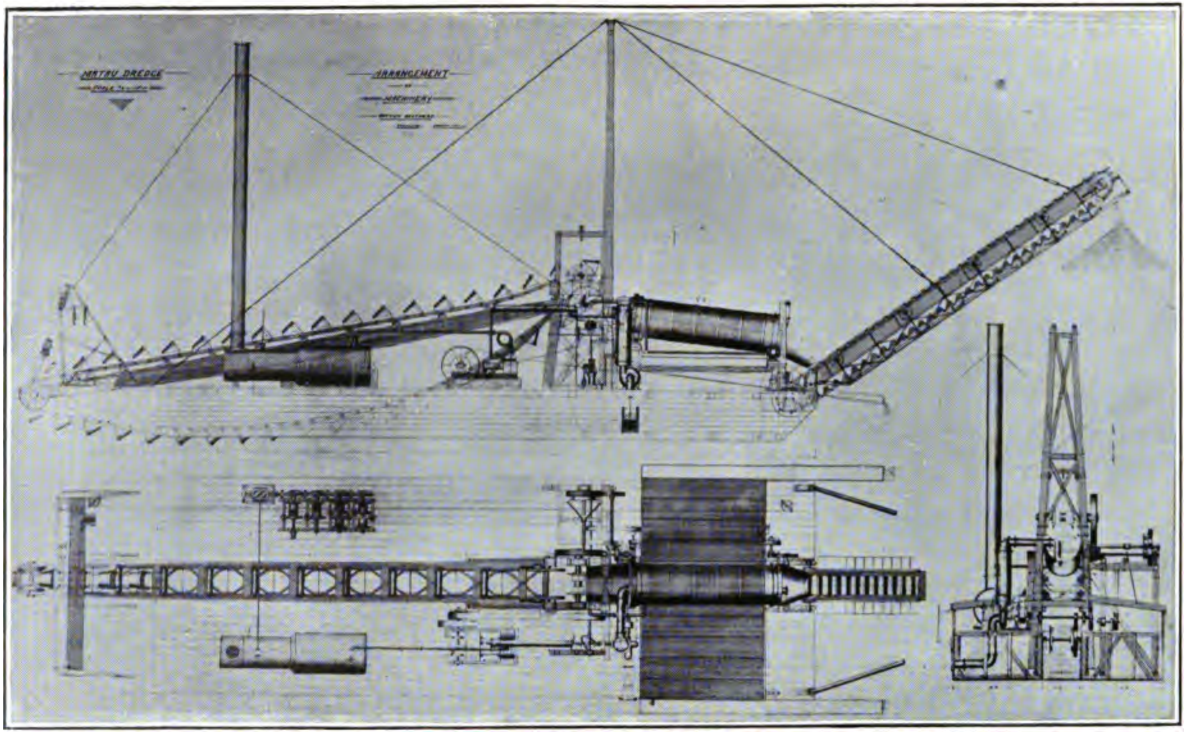
means to prevent the gritty water from the pump getting into the bearings.

The hydraulicing water pump, the outer casing of which is better cast in one piece, and is fitted with doors on both sides to give access to the runner. An electric light plant must be capable of running the necessary incandescent lamps on the pontoon, and four arc lamps for use outside when working at night. Two nozzles are used for breaking down the alluvial wash and debris. The width of the sluice box is determined by the amount of the materials and water delivered by the gravel pump. The correct length and pitch of the sluice can only be decided after direct experiment with the special class of alluvial wash to be handled, and the quality of the tin ore to be saved.

*For tin I have not much faith in bucket dredging where there is much overburden to deal with, but where the alluvions are of river or creek formation and fairly clean, they are efficient in dealing with stream tin. One has to consider the specific gravity being so much less than gold, the material cannot be treated so fast as with gold. It is all very well to say we can strip and elevate the overburden, then deal with the pay dirt. That is so, but it cannot be done profitably, owing to the delicacy with which tin must be treated. To work tin country efficiently in the form of streaming, the gravitation system or the centrifugal pump system is the most profitable and satisfactory. When working tin, a long run is necessary. It is always advisable for dredge men to be careful when working in albite granite alluvials, as tin in respectable quantities is sometimes evident, and at times sufficient is saved to pay working expenses of an ordinary dredge—sometimes an oxide, sometimes a sulphuret. It will be readily understood how difficult it is to save tin and gold when the specific gravity of tin is at 4 and 5 and oxide at 6 and 7, while gold stands at from 12 to 20, gold being seven times as heavy as gravel, while tin is so much lighter in proportion. The perforated drop riffle will be found the most efficient in existence for tin, owing to being able to set it to a dead level or fall, as required to deal with any specific gravity. In hydraulic sluicing I have been able to save tin and fine gold together. All alluvial men are not conversant with tin when they get it in concentrates. Using the blow-pipe with carbonate of soda, a globule of tin is obtained. When tin is in very minute quantities, add a little borax, and by this means even ½ per cent. may be detected.

(4) *Bucket Dredge with a Sluice Box.*—This dredge, although capable of treating the same quantity of stuff as the screen bucket dredge, is somewhat limited in operation, because it cannot work at more than 4 feet above the water and not more than 25 feet below the water level. It also requires, if it is to be worked at its best, a swift current in the river to carry away the debris—the disposal of the tailings being always the great trouble with this type of dredge. One great advantage that this type of dredge possesses is its simplicity, having a smaller amount of machinery to operate. On the other hand,

* H. L. Lewis "Gold and Tin Dredging Practice," 1905.



ARRANGEMENT OF MACHINERY ON BUCKET DREDGE.

where flat stones occur in the wash it renders the working more expensive, because it causes considerable loss of ore, and necessitates cleaning up more frequently. The most suitable wash for this dredge is one composed of coarse gravel and small round pebbles, but under no conditions does the author recommend this class of dredge being installed without the previous advice of a skilled expert.

The author does not know of any of this type of dredge being employed in dredging for tin ore.

(5) *Bucket Dredge with Screen and Elevator.*—The dredge mostly in use at the present day is of the endless chain screw and elevator type. An endless chain of buckets is carried on rollers resting on a steel ladder. The upper end of this ladder is swung on a pivot shaft attached to a frame at a convenient height above the deck of the dredge. The lower end of the ladder is suspended to the gantry frame by cables, which pass over sheaves to a drum on a winch, so that the ladder may be raised or lowered to feed the buckets. The buckets pass over tumblers at the upper and lower ends of the ladder. The power to drive the bucket line is applied at the upper tumbler through gears. The material, as excavated by the bucket, is dumped into a shoot, and from this shoot is fed to revolving or shaking screens. The proper arrangement of this screening and sizing apparatus has a very considerable influence on the successful saving of the tin ore. When dredging clayey matter "retards" should be riveted into the revolving screens so as to break it up, a jet of water should constantly play inside of the screen, which allows all rocks of from 12 in. to 24 in. in diameter to pass out.

The best working size for the apertures in the screen is between 1 in. to 6 in. in diameter, after passing through the screen the pulp is elevated by a large centrifugal pump, this has the effect of disintegrating the material and is allowed to pass over a grizzley before going into the sluice below. The distance between the bars is determined by the nature of the material treated, but the grizzley should take out all large heavy material which will interfere with subsequent saving operations.

This sluice is about 3 ft. wide and 2 ft. deep, it may be found necessary to widen this sluice box to allow a larger settling area, ripples should be placed at intervals to make an undercurrent which allows the fine material to settle.

The same operation is repeated if found necessary again, the contents of the sluice is passed over a grizzley, the finer material falling into a shallow box, about 1 ft. deep from 5 to 6 times the width of the sluice, this box gradually tapers towards the outlet. This part of the sluice should be made 15 ft. long and from 24 in. to 18 in. wide.

This dredge, so far as its powers of working go, will treat almost any wash, its principal features being that, as compared with the limited range of the sluice-box machine, it can deal with wash at a depth of 50 feet below and 50 feet above the water level, and deliver the tailings to a height of 70 feet above the water, making a range of 100 feet in all. On the other hand, this class of dredge has more machinery to keep up, the tables can be cleaned up continuously

without stopping the dredge. The principal merit in this machine is the splendid manner in which it delivers the tailings. The question of how to deal with the tailings was, up to a few years ago, one of the most difficult problems in connection with all dredging propositions for metals.* It remained for Mr. W. H. Cutten, of New Zealand, to solve the problem. Up to 1894 the dredges in New Zealand (which might be described as the birth-place of dredge mining) were only working the river beds and low beaches, but could not work the higher banks, on account of the difficulty in stacking the tailings clear of the stern. In June 1894 Mr. Cutten designed and constructed a machine now called a "tailings elevator," which consisted of a ladder fixed to the dredge, and projecting over the stern at an angle of about 33° to the water level.† On this ladder there is a continuous chain of buckets, or rather trays, working over tumblers at the top and bottom of the ladder. The rough portions of the tailings, after being washed and separated from the fine by a revolving screen, were delivered into the elevator, carried up, and stacked to any desired height or distance from the stern of the dredge according to the length of the elevator. This was the first attempt to deal with the difficulty.

The following is the latest form of Tin Dredging plant at present in operation :—

The dredging plant at the Y Water Holes, Emmaville, N.S. Wales, will be the largest yet erected in the Commonwealth. It will include two pairs of compound special dredge type of engines of heavy construction, designed for a working pressure of 160 lbs. per sq. in. The bailers, three of which will be installed, will be 22 ft. long by 7 ft. 6 in. diameter, and weighing 16½ tons each. They are designed for a working pressure of 155 lbs. per sq. in. The stacks will be 60 ft. high from footplate. The gravel pump will be of the Kershaw pattern centrifugal pump, 14 in. intake, and will embody all the latest improvements. The nozzle pumps, of which two will be installed, will be of 16 in. right and left hand, of special construction, arranged to operate in series or compounds, and capable of giving a nozzle pressure of about 75 lbs. per sq. in. The whole of the machinery will be erected upon a pontoon of

* It is interesting to note the way in which the tailings from a dredge will stack up under different conditions. A dredge with a single sluice-box, into which the whole of the washdirt is discharged, will require about 20 per cent. more room to stack the tailings than they formerly occupied; but one fitted with a revolving screen and elevator will require fully 33 per cent. more room, due to the fact that the fine dirt is separated from the coarse, and only gets partially mixed when discharged at the stern by elevator. In this case the fine dirt, and all that passes through the perforations in the revolving screen, is delivered close under the stern of the dredge, and settled on the bottom, while the coarse dirt and stones are carried up the elevator and stacked on top of the fine stuff, which gets no chance of being mixed with the stones. The interstices between are not filled, consequently much more room is required.

† The principle of the tailings elevator is evidently not quite understood by some dredge-makers, as the author has seen some designs in which the angle of elevation, instead of being 33°, is only 18°, which would tend to cause immense leverage and consequent loss of power.

TYPICAL BUCKET DREDGE, SHOWING TAILINGS ELEVATOR.

the following dimensions : 65 ft. by 45 ft., with a depth of 5 ft. The plant will be capable of treating from 100 to 150 cub. yds. of solid material per hour to a depth of 60 ft.

The question of size and capacity of the dredge is one on which opinion differs, but at present all efforts are bent towards increasing the capacity of the dredge. The dredge of a monthly capacity of 40,000 to 45,000 yards is more easily kept in repair, for all parts are comparatively light. Still, the labour cost, which is one-third of the actual expense of working a dredge, is the same in a dredge of 40,000 yards capacity as it is in a dredge of 70,000 yards capacity. The increase in power is in less proportion than the increase in the number of yards handled, and therefore the larger dredge is unquestionably the greater net producer. However, there is an economical limit to the capacity of a dredge. At the present time this limit may be said to have been reached in the case of dredges handling 70,000 to 80,000 cubic yards per month. Still the tendency is to larger, and it is not at all impossible that within a short time dredges of 100,000 cubic yards' capacity will be the most economical.

There are four distinct functions which a dredge must perform :—

(1) Excavate large definite quantities of gravel.
(2) Sluice all the gravel the buckets or pump can raise.
(3) Save the tin.
(4) Dispose of the tailings.

The dredging part of the machine was developed first. The size and strength of all the machinery had to be increased to withstand the changing and immense stresses put upon it in dredging gravel. Actual working experience has been the key to the problem which had to be met. What this experience has taught may be illustrated by the statement that the weight of the buckets alone has been increased from 500 lbs. to 1,200 lbs. each. Machinery on the dredge, as a whole, has been increased from 150,000 lbs. to nearly 500,000 lbs. in the larger machines, whilst the capacity of the dredges has been increased from 20,000 to 75,000 cubic yards per month.

It takes more horse-power to dredge tight gravel than it does to dig loose gravel, and dredging large quantities of gravel necessitates an equivalent amount of power. The question of horse-power behind the bucket line or suction-pump is determined by the class of deposit to be treated. In bucket dredging, as a fundamental proposition, the machinery must be designed to withstand the maximum pull which can be exerted by the driving machinery. If a 100 horse-power motor is driving the buckets the strains must be figured, not to withstand the normal pull of this motor, but the greatly increased pull as it slows down to the standing point. To this figure add the strain resulting from the surging of the dredge when digging tight gravel.

Variable speed motors have been generally introduced to give better control of the machinery, and to regulate the speed of the bucket chain.

The rated horse-power of the 45,000 yard dredge is up to 60; that of the 75,000 yard machine is 120. The actual horse-power used is about 50 for the small dredge and 100 for the larger one.

The "wear and tear" on dredging machinery is great, but the wearing parts are lined largely with manganese steel, and these wearing parts have been made readily and easily replaceable.

The dredging power of the machine was developed more rapidly than the screening and tin-ore saving part. The dredges were digging more gravel than they could wash and screen. However, this defect can be overcome by increasing the screening, and adding more water and greater tin-ore saving area. It is impossible to save tin in a narrow sluice, and it is also necessary to have an adequate arrangement of sizing and screening apparatus. The most difficult material to sluice being fine heavy alluvial, where this is met with the sluicing is much facilitated by allowing a number of well-rounded stones, 4 in. to 5 in. in diameter, to go into sluice, the result being that the fine material does not pack so readily and allows a free action of the water. It is a common fallacy to suppose that any dredge will answer. To be successful the dredge must be designed to suit the conditions under which it is proposed to operate, the amount of material to be handled, and the character of that material.

The successful recovery of the tin ore has been a difficult problem, and improvements in the present methods are still possible. A long tail race is absolutely necessary for the successful recovery of tin ore.

A dredge must be kept running as near twenty-four hours a day as possible, for when a dredge stops the producing part of the plant stops, while the expenses continue. Good judgment in the management of a dredge will minimise the time lost. Duplicates of the essential parts of the dredge should be kept on hand. All wearing parts should be provided for beforehand, so that when a break occurs it can be mended with the least possible delay. Care in this respect is more necessary in the dredge than in the mill, for in the mill you can hang up one battery for repairs or renewals while the others are working, but with the dredge the most trivial accident will stop the whole plant until repaired.

CHAPTER XIX.

METHODS OF TIN ASSAYING.

THERE is no method to compare in rapidity, cheapness, and comparative accuracy with the tests made by the vanning shovel or prospecting dish.

The former is generally used for testing the values of crushed ore in dressing sheds, and the latter for washing off prospects from alluvial drift.

Mr. Richard Pearce, in the *Engineering and Mining Journal* of New York, published the following account of some investigations made for the purpose of establishing the amount of inaccuracy that occurs in vanning.

Mr. Pearce did all the vanning—that is, mechanical assaying of tin ores—at Dolcoath when a young man of 20 years, so that his investigations into the methods still in vogue there, after he himself has added more than 40 years of metallurgical work to his youthful experience, represent results of peculiar interest to professional men.

From the above it will be gathered that Mr. Pearce is entitled to speak with some authority. Having pointed out the difficulties encountered in investigations of this description, he says: "It occurred to me, after much thought on the subject, that some reliable data as to the extent of these tin losses might, perhaps, be obtained by preparing (synthetically) a mixture of known ingredients, resembling in composition and general character such crude ores as are treated in Cornwall, and then experimenting upon it. For this purpose a gangue was selected, consisting mainly of quartz, chlorite, small quantities of pyrite and arseno-pyrite, and containing, of course, no tin. A sample of cassiterite was selected from a Bolivian specimen, uniform in character and containing 70·38 of metallic tin as determined by careful assay by the cyanide of potassium method. The mixture was carefully prepared, consisting of 150 parts, by weight, of the gangue, with 5 parts of the rich Bolivian tin ore, by pounding in a steel mortar until the whole of the material passed through a 30-mesh screen. Great care was taken to prevent mechanical loss in the crushing and preparation of the mixture, and the actual loss of material sustained did not exceed 0·4 per cent. After passing through the 30-mesh screen this material was still further ground in a mortar to a pulp sufficiently fine for the ordinary determination of oxide of tin by vanning. The mixture prepared as

above should contain 3·225 per cent. tin oxide of 70·38 per cent. metallic tin, or a total percentage of metallic tin in the crude material equal to 2·269 per cent.

"The entire sample was carefully mixed and divided into three portions. One portion was sent to the assayer at Dolcoath, with a request that he should determine in the usual way the percentage of tin oxide (black tin) it contained, and return the concentrates for inspection. The second portion was assayed, by vanning in the same way, by myself; and as the results appeared to disagree, the third sample was sent to Mr. Reynolds, the instructor in vanning at the Camborne School of Mines, for determination by vanning. The concentrated produce (tin oxide) obtained from vanning by the two experts was returned for the purposes of comparison. The results are shown in the following table:—

	Tin Oxide.	Tin.	Metallic Tin.	Tin Recovered.	Tin Lost.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Dolcoath - - -	2·970	at 60·00	1·782	78·532	21·468
R. Pearce - - -	2·530	70·60	1·786	78·713	21·287
Reynolds - - -	2·360	75·09	1·772	78·096	21·904
Mean - - -	2·620	—	1·78	78·447	21·553
Actual contents -	3·225	—	2·269	—	—

"The concentrated product in each case was assayed for tin by Mr. E. V. Pearce, of Williams, Harvey & Co., tin smelters, at Hayle, Cornwall, after digesting for some time in HCl. for the purpose of dissolving out any iron oxide present. The percentages of tin contained in the three vanned products is shown in the second column.

"The Dolcoath result exhibits a low degree of concentration, which is proved by the determination of the iron in the hydrochloric acid solution resulting from the preliminary chemical treatment of the concentrates samples; this solution gave 10·2 per cent. Fe_2O_3, as compared with 6·46 per cent. and 2·5 per cent. found in the other samples by Pearce and Reynolds respectively. It will be seen from the above results that in the assay, by vanning, of an ore containing 3·225 per cent. of tin oxide, a loss is sustained by the actual method in vogue of 21·55 per cent., and we may reasonably infer that an ore having a lower assay value, such as is produced in Cornwall at this time, would suffer a correspondingly increased percentage loss in vanning. It is more than probable that the mixture offered more favourable conditions for concentration, from the fact that the tin oxide was entirely free and contained no particles of gangue attached to it, such as would decrease the specific gravity considerably, thereby inducing an increased loss. We may reasonably infer, therefore, that the results obtained from vanning the mixture indicate a larger percentage of saving than can

possibly be obtained by a similar treatment of the ore in its natural state as it comes from the mine."

The latest, best, and most accurate methods of the assay of tin ore are published in a work called *The Assay of Tin and Antimony*, by L. Parry,* who gives the following account :—

"*Tin Ore.*

"The dry assay of tin ore is only to be recommended for works purposes, mines, or for prospectors. It is not accurate enough for buying and selling on equitable terms, having regard to the amount of money hanging on a single assay and the increasing keenness of competition.

"*The Cyanide Assay* is of the most general applicability, but (*a*) where the ore is pure and contains much Fe_2O_3 it should be digested with strong HCl, provided the tin is present as cassiterite. (*b*) If much pyrites is present it should be evaporated to dryness with HNO_3 before extraction with HCl. These operations may be conveniently performed in a 6-in. evaporating basin with a clock glass cover. Oxide of lead, if occurring in tin ore, is very difficult to extract completely, even with strong hot HCl, whilst HNO_3 often removes only half of it. Take 20 grms. dried ore, 20 c.c. of strong HNO_3, and about the same amount of water, and evaporate cautiously to complete dryness. Add 100 c.c. strong HCl and digest for half-an-hour just below the boiling point. Dilute with an equal bulk of water, filter, and wash by decantation until the washings are free from HCl. Ignite the filter paper and add the ash to the cleaned residue of ore in the dish. The HCl extract will *usually* contain *most* of the iron, arsenic, antimony, etc., and will in general be free from tin, but should always be tested or assayed for tin (see wet assay). It is *never* safe to assume that the cleaned residue is free from metallic oxides other than SnO_2, though the assumption is frequently made. Dry the cleaned ore and mix it with an equal weight of cyanide (98 per cent. Au—not commercial cyanide). Take a small dry crucible and charge in 10 grms. cyanide, then the above mixture, and finally 10 grms. cyanide as a cover. Place in a fire at a low red heat and fuse gradually, increasing the heat to bright redness at the finish of the fusion, which should not take more than ten minutes. Allow the assay to become quite cold in the crucible, and when cold break out the button, and either re-melt it by dropping it into a crucible containing melted borax, or under palm oil in a ladle, or cut it in two and boil out the adhering cyanide with water. The button should in every case be assayed by a *wet* method for *tin*, otherwise the result is a mere guess and may be very misleading, no matter how much the ore has been cleaned or however pure the ore is supposed to be, or however clean the metal appears to the eye. The use of the term "fine tin" has been already referred to in the introduction, and it is only necessary to add here that Sn is a definite entity, while "fine tin" is an

* L. Parry, "The Assay of Tin and Antimony." (London : "The Mining Journal.")

expression which awaits definition. Further, it is quite as bad to assay such a button by oxidation with HNO_3 and weighing the oxide residue as SnO_2—that would be merely making the same unjustifiable assumptions (in another form) as to absence of certain impurities, which are involved by weighing the prill as *tin*. The button must be assayed positively for tin by a method which shall ensure the elimination of the interference of every possible impurity, and that, in practice, means assaying the button for tin by a volumetric method. Of course, if this procedure is systematically followed—(and any other is illogical as an assay, and so uncertain as a valuation basis as to be inexcusable on account of the high price of tin), the results will always favour the buyer. The remedy is not to attempt to counteract this "low" tendency, which is inherent in any dry assay, by balancing an unknown "high" tendency (impurities) against it (the net result of which is, in practice, to favour the seller), but to use a wet assay throughout.

"Of other dry methods of assaying tin ore, the Cornish tin assay is no doubt useful on mines as a comparative test, where the quality of the ore remains fairly uniform, whilst the vanning test is also most useful to prospectors and on mines.

"The German assay of tin ore by mixing with oxide of copper and fusion for white metal does not appear to possess any advantages over the cyanide assay as regards accuracy, and is an exceedingly complicated method.

"The method of fusing tin ore with Na_2CO_3 and borax in a luted carbon-lined crucible, in the muffle, is said to give very perfect reduction of the tin.

"Hallet's method—fusion with KHF_2, solution in H_2SO_4, and precipitation of the tin as metastannic acid on dilution and boiling, seems to be a good assay, but is in reality a wet method.

"THE WET ASSAY OF TIN.

"*Gravimetric Assay by Weighing as SnO_2.*

"Bi, Pb, As, Sb, Fe, W, Si, should be absent.

"The tin from 1 grm. of material, separated either as metal or sulphide, is treated with 20 c.c. of dilute HNO_3 (1 : 1) in an evaporating dish, and evaporated almost to dryness. It is diluted with 50 c.c. hot water and boiled, then filtered, the residue well washed with hot water, dried, and ignited in the muffle in a small porcelain dish. When cold, weigh the SnO_2. It contains 78·7 per cent. Sn.

"The tin in bronze coins and tin copper alloys free from Sb, Pb, As, may be estimated this way, but its application to solder, metal from crucible assays of tin ore, and the sulphide precipitate from tin slags is inaccurate.

"If solder is treated in the above manner, the residue consists of SnO_2 and SbO_2 and some PbO. Multiply the weight of residue from 1 grm. of solder by 78·7, and the result, less 1 per cent. deduction for

lead, may be taken as the sum of the percentages of tin and antimony in the solder.

"*Gravimetric Assay by Electrolysis.*

"This assay is fully described in Classen's *Chemical Analysis by Electrolysis.*

"*Volumetric estimation with Ferric Chloride.*

"When ferric chloride is added to a strong HCl solution of stannous chloride it is immediately reduced to ferrous chloride, and stannic chloride is formed at the same time. *One drop* in excess of the ferric chloride gives a decided yellow colour to the previously colourless solution, provided the solution is hot and strongly acid. The nearer the boiling point and the greater the concentration of HCl in the solution, the more rapid is the completion of the reaction. A solution of $FeCl_3$ in dilute HCl, of which 100 c.c. = 2 grms. Sn, is employed. In the assay the addition of $FeCl_3$ from the burette cools the solution somewhat, so that the finish is rather slower than the commencement of the reaction, both owing to dilution and consequent lowering of the temperature, and to the presence, in increasing concentration, of ferrous chloride in the solution, but in any case the titration should never take more than a minute if worked as directed. $FeCl_3$ gives a far stronger colouration in a hot, strongly acid solution than in a cold, faintly acid solution. The titrations cannot be done by gas light or electric light, and should always be effected in the day time. In an emergency they may be done by magnesium light.

"The equation representing the chemical change is $2\ FeCl_3 + SnCl_2 = 2\ FeCl_2 + SnCl_4$. The presence of chlorides of lead, zinc, aluminium, iron (ous), cobalt, nickel, antimony, (ous), copper (ous), cadmium, does not affect the quantity of $FeCl_3$ required; the presence of $FeCl_2$ in quantity somewhat retards the finish and lessens the delicacy of the colour indication; Cu_2Cl_2 reduces $FeCl_3$ with formation of $CuCl_2$, but $SnCl_2$ reduces $CuCl_2$, and the net result of this is that not a trace of $CuCl_2$ is formed until all the $SnCl_2$ is converted into $SnCl_4$—the next drop of $FeCl_3$ forms a trace of $CuCl_2$ which gives a similar colour indication to that of $FeCl_3$ itself; $CoCl_2$ and $NiCl_2$ give highly coloured solutions which render the recognition of the end point difficult—one way of remedying this is to dilute the solution somewhat with boiling water, which removes the blue colour, but of course renders the reaction slower, and lessens the colour intensity of the drop or two excess of $FeCl_3$; $SbCl_3$ is not converted into $SbCl_5$ by $FeCl_3$, and under the conditions of the assay neither $SbCl_3$ nor $SbCl_5$ ever occur in the solution. $Cu_2\ Cl_2\ CoCl_2$, $NiCl_2$ are rarely present, also $CdCl_2$ and Al_2Cl_6; $FeCl_2$ is often present to begin with, and $ZnCl_2$ and $PbCl_2$ are generally present in greater or less amounts. $BiCl_3$ and $HgCl_2$ are reduced to metal by $SnCl_2$, but Bi and Hg would be separated with iron. Precipitated Sb, Cu, As, are attacked by hot acid ferric chloride and blue oxide of tungsten is affected by it, but the assay method excludes the presence of these substances during titration.

Acid solutions of $SnCl_2$ very readily oxidise by exposure to air ; the method of dissolving the tin from the state of metal by boiling with HCl in an atmosphere free from oxygen excludes the formation of $SnCl_4$ if the operation is carried out as subsequently directed, and if the solutions are titrated as soon as ready and at the boiling point, the oxidation tendencies are completely eliminated. Briefly the best conditions are (1) Solution from the state of metal as rapidly as possible in a non-oxidising atmosphere, the solution being brought to the boiling point before solution is complete. (2) Use of strongest and purest HCl. (3) Bulk 150—250 c.c. (4) Titration rapid and at the B. Pt. (5) Strength of $FeCl_3$ 100 c.c. = 2 grms. (6) Absence of precipitated Sb, As, Cu in the solution.

" From the dilute peroxidised HCl solution of Sn, Sb, Hg, Bi, As, Cu, Pb, Cd, Zn, Co, Ni, Fe, P, the Sn, Sb, As, Cu, Hg, Bi, and some Pb and Cd are separated as sulphide by H_2S if it is desired to separate from Co, Ni, Fe, P. The sulphide precipitate is re-dissolved in HCl and KClO, and the solution reduced by heating with iron wire. The As Sb, Cu,Hg, Bi, are precipitated in the metallic form, and the solution (which must be strongly acid to avoid precipitation of $SnOCl_2$) is filtered and neutralised with thin strips of zinc. The action finished, the mother liquor, after testing for tin with H_2S water, is poured off as completely as possible, and the residue of spongy metallic tin and lead and undissolved zinc is dissolved in the same flask in about 200 c.c. of pure HCl, the flask being provided with a rubber cork and leading tube, and the liquid is brought to a boil as rapidly as possible ; a piece of pure zinc about the size of a pea is added to assist in preserving a non-oxidising atmosphere of hydrogen and hydrochloric acid in the flask until the liquid clears and boils. As soon as everything is in solution and the liquid is boiling, the flask is removed from sandbath or plate and titrated immediately with ferric chloride. The ferric chloride should be free from ferrous chloride, nitric acid, chlorine and arsenic, and the solution should contain 300—500 c.c. HCl in two litres. It is best made up from a concentrated stock solution in HCl, made by dissolving piano wire as directed subsequently. If the assays turn dark greenish after titration, the $FeCl_3$ solution is contaminated with HNO_3. The $FeCl_3$ may be made up also by dissolving 180 grms. of the yellow commercial lump salt, which is $Fe_2\ Cl_6\ 12\ H_2O$, in about 200 c.c. HCl and evaporating it to dryness. The residue is dissolved in 300 c.c. HCl, and diluted to two litres. The solution is standardized against one grm. of the purest tin obtainable, filed with a fine file. This is weighed into an 8 oz. flask, and the flask is about three parts filled with pure HCl, rubber cork and leading tube inserted, and boiled (but not too rapidly) until solution is complete ; then titrated at once.

" Pure tin is more readily obtained from smelters of tin ore than from dealers in chemicals. The writer once ordered some " pure tin for standardizing purposes " from a firm of wholesale chemists, and received metal holding three per cent. Sb.

" It is rarely necessary to complicate the assay by separating the tin as sulphide. Having once got everything in solution, reduce with iron

wire, filter, and precipitate on zinc. This method has been repeatedly checked on made up metals of known composition containing varying amounts of Sn, Pb, Cu, Sb, and the results are in every case so close as to leave no doubt whatever that the method is extremely accurate; indeed it is much more accurate than the electrolytic assay, on account of the complicated separations which the latter involves, and is incomparably quicker.

"The favourite objection to the ferric chloride assay is the oxidation tendency of solutions of $SnCl_2$. The method, if properly worked, overcomes this completely. It has also been objected that five or six drops of ferric chloride solution are necessary to give a perceptible colour indication. This is quite incorrect; one drop in excess of $FeCl_3$ is ample if the operator possesses normal colour vision. It is also stated that Sb dissolves in HCl; this is not the case. It is true that finely divided Sb in contact with air and HCl slowly dissolves, but even then $FeCl_3$ does not oxidise $SbCl_3$; and further, under the conditions of the assay the absence of Sb is ensured by the iron wire separation. In direct ferric chloride assays on solutions from metal filings, the assays, so far from being too high through Sb dissolving, are too low because of Sn retained with the black powder, and it should also be remembered that metallic tin precipitates antimony from solution.

"*Volumetric Estimation with Iodine in Acid Solution.*

"The dilute acid solution of metallic chlorides, which should not be more than about 50 c.c. in bulk, and should be contained in a 4 inch beaker, is reduced by heating with a clean piece of iron rod resting in the solution against the side of the beaker, which is covered by a watch glass. The whole is heated to 80° or 90° C. (not to boiling) over a Bunsen flame; five or six assays may be conveniently heated in a small frying-pan sandbath. The assays are heated for 20—30 minutes after they have lost their original red, yellow, or greenish colour. The Sb, As, Cu are precipitated, and the $SnCl_4$ is assumed to be reduced to $SnCl_2$; in practice this assumption is found to be justified, though it is really one of the weak points of the assay. The assays are cooled in a basin of cold water, and when cold the watch glass and rod are rapidly washed with a little cold boiled water, starch paste added, and the solution titrated rapidly with iodine. It is not necessary to remove the black precipitate of Sb, As, Cu, as the finishing point in the case of $Sn\,Cl_2$ and iodine is so sharp; but the finely divided metallic precipitate sometimes seems to *slowly* remove the blue colour. The iodine solution is made up by dissolving 21·32 grms. iodine and 45 grms. pure KI in about an inch of water in a small beaker and diluting to one litre. 100 c.c. = 1 grm. Sn. Not more than ·5 grm. Sn should be present in the assay. It has been proposed to increase the accuracy of this assay by titrating in an atmosphere of CO_2."

Assay of Tin Ore.

Tin ores are often exceedingly complex; they may contain in addition to stannic oxide, ferric oxide, and silica, some or all of the following substances—bismuth, copper pyrites, iron pyrites, mispickel, wolfram, titanic acid, lead oxide, antimony oxide. Antimony and arsenic are common impurities, especially in South American ores. Contrary to a statement in "Crookes' Select Methods," the writer's experience is that antimony is almost invariably associated in small quantities with tin ore. It should be apparent that complete solution of the ore is absolutely essential in every case, in order to systematically ensure the complete extraction of the tin and its quantitative determination. Any method which does not involve complete solution of the ore is quite unreliable as a *method*, although it may often yield correct results. Further, the final determination of the tin should always be effected volumetrically; if a gravimetric estimation is adopted the assay develops into an academic research, owing to the number and complicated nature of the separations necessary to ensure that no possible impurity may score as tin; while if such thorough separation is neglected, the results obtained are quite unreliable.

The following methods have been proposed and used for the wet assay of tin ore:—

1. Fusion with alkalies or alkalies and sulphur.
2. Continued agitation with zinc and HCl.
3. Reduction of the cleaned stannic oxide in hydrogen and calculation of the tin from the loss in weight, which is assumed to represent only the oxygen of the stannic oxide.
4. Cleaning with HCl, and reduction with cyanide in a porcelain crucible.
5. Fusion with potassium hydrogen fluoride, solution in sulphuric acid and precipitation as metastannic acid by dilution and boiling.
6. Reduction in coal gas or hydrogen, and extraction with HCl and HNO_3, combined with fusion of the siliceous residue with Na_2CO_3 and borax in a platinum crucible and solution of the melt in HCl.

The first method is now hardly ever used, being tedious and uncertain. The second method, agitation with zinc and HCl, is very slow; it may occasionally give all the tin, but there can be no certainty whatever about such a method, and the same remark applies to the third method, calculation of the tin from the weight of oxygen lost by reducing the stannic oxide in hydrogen after presumably purifying it from other metallic oxides by cleaning the ore with acids; rapidity is claimed for this method, but the assumptions as to complete reduction of the tin and absence of other metallic oxides reducible by hydrogen are vital objections, and render the method unsound from both a scientific and commercial standpoint. Method four, reduction of cleaned ore with cyanide, is in reality a dry assay, notwithstanding the use of the porcelain crucible, and when the metal obtained is assayed for tin, must

necessarily give results which are lower than the tin contents. It is not denied that in many cases the results will only be very slightly under the actual percentage, but one can never be certain of this; often, indeed, results obtained in this way are two or three per cent. too low. If the button of metal is not assayed for tin, the results obtained may be either a little too low, correct, or up to as much as four or five per cent. too high. The method is not sufficiently certain for the commercial valuation of tin ores. Method five (Hallet's method) is logically admissible, provided that the precipitated metastannic acid is not merely ignited and weighed as stannic oxide, but is redissolved and the tin carefully separated. This, however, complicates the method somewhat. Method six is the most practical method of assaying tin ore, which ensures at the same time accuracy and reliability as a *method*, and it alone will be considered here.

Description of Method.

Tin ores may be either pyritic or non-pyritic. Pyritic ores must be, and non-pyritic ones may be, treated with HNO_3 before reduction, as sulphide of tin is volatile at a red heat. Five grms. ore, ground as finely as possible in an agate mortar, is treated in an evaporating basin with clock glass cover with 20 c.c. dilute HNO_3, and carefully evaporated to complete dryness. The residue is digested with dilute HNO_3 and filtered. The washed residue is dried, ignited in the dish, transferred to a porcelain boat and heated to a low red heat for 3 to 4 hours in a slow current of hydrogen or coal gas. Coal gas is much more convenient to use, and quite as effective as hydrogen. The boat is $2\frac{1}{2}$ inches by $\frac{1}{2}$ inch, and two at a time are placed in a porcelain tube 12 inches long and $\frac{3}{4}$ inch bore, which is then placed in the reduction furnace. A very convenient form of gas reduction furnace with clay body, brass gas jets, and asbestos rings to fit over the ends of the tube against the clay covers, is made in 6-inch lengths by Messrs. Fletcher, Russell & Co. of Warrington. The ends of the tube should project about 3 inches from each end of the furnace, and should be closed with rubber corks fitted with glass tubes as shown; the escaping gas (about 2 bubbles per second) is passed through dilute HCl.

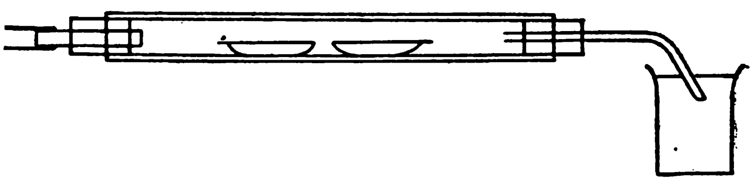


FIG. 36.

The water through which the gas escapes should not be thrown away, but saved, and every now and then the tube should be washed out with HCl and $KClO_3$, and the two solutions tested for tin as a check, against, for instance, loss by volatilisation through sulphur in the coal

gas. A two-way gas branch is used; one jet supplies gas to the tube, the other supplies the gas for heating to the jets of the furnace. The boats are allowed to cool in the furnace, and when cold each boat and its contents is transferred to a 400 c.c. beaker and treated with 100 c.c. HCl and 5 c.c. HNO_3, the assay being allowed to stand in a warm place until the action abates, when it is boiled for a few minutes, diluted with an equal bulk of water and filtered. The residue is well washed with hot acid water, then with hot water, is dried, ignited and fused with four or five parts of a mixture of fusion mixture (free from chlorine) and borax in a platinum crucible, and the melt dissolved in HCl and precipitated with zinc as usual. The residue rarely holds more than a half per cent. of the total in the ore.

"The main solution is made up to 500 c.c. and the equivalent of 1 grm. is pipetted into an 8-ounce flask, reduced with iron wire and filtered; the filtrate is precipitated with strips of sheet zinc as usual, and the metallic sponge dissolved in HCl and titrated with ferric chloride."

Any copper in the tin ore is found in the HNO_3 solution, though traces may remain with the SnO_2. In the iron wire stage, the arsenic which escaped extraction with HNO_2 and volatilisation in the reduction tube is partly evolved as AsH_3, and partly precipitated with antimony in the metallic form. It comes down as a brown flocculent deposit which contains three or four per cent. of its weight of tin. As there is generally only a few per cent. at most of As in a tin ore, the loss of tin from this cause is quite negligible, but as a check one should save the iron wire and precipitates and filter papers and examine them from time to time for tin. It will be found, as in the case of the deposit in the tube and the dilute HCl through which the escaping gas bubbles, that only the merest traces of tin are lost in these operations. Further the HCl solution of the reduced metal may be done in a conical flask with rubber cork and leading metal tube dipping under water, to assure oneself that there is no appreciable loss by volatilisation of $SnCl_4$.

If the ore contains wolfram, the tungsten is mostly found as WO_3 in the residue from HCl and HNO_3 extraction of the reduced metal, from which it may be removed before fusion, with AmOH. Any tungsten which gets into the main solution comes down as blue oxide with the iron wire precipitate, and any which is fused with $KNaCO_3$ and borax should be removed by reducing the HCl extract of the melt with iron wire, before precipitating with zinc. In general, all the antimony and some of the lead in the ore will be found in the main HCl solution, whilst some of the lead will be obtained in the HNO_3 extract.

NOTE.—After the HNO_3 evaporation the residue may be boiled with HCl (40 or 50 c.c.) diluted and filtered, though in this case the extract must be tried for tin as a matter of precaution. It will in general hold all the copper and most of the arsenic, antimony, lead, and iron, though one can never be sure that the residue is free from the oxides of these metals. Occasionally this HCl extract will hold a little tin. The residue is reduced in the usual manner.

One of the most difficult assays in tin is to accurately determine the amount lost in the sluices and tailings. On that account the method given below is of great practical value ; it was published in a paper by George L. MacKenzie before the Institution of Mining and Metallurgy, November, 1903.

METHOD.

Clean the ore with *aqua regia*. Reduce the stannic oxide to tin by ignition in an atmosphere of coal gas (used as hydrogen). Dissolve out the tin with hydrochloric acid and free chlorine. Precipitate as stannic sulphide by passing hydrogen sulphide. Convert the stannic sulphide to oxide by ignition in a small weighed Berlin crucible and weigh as stannic oxide.

Take from 1 to 5 grm. ore according to richness so as to get a weighable quantity of stannic oxide—1 grm. of a 2% ore is sufficient : if the ore is very poor two lots of 5 grm. may be combined after reduction separately in the combustion tube.

Crushing must be very fine, the sample well mixed and not shaken about afterwards, or the tin oxide will get concentrated in the lower part of the sample. In quartering samples the finest dust left on the sampling paper will probably be the richest.

1. *Cleaning the Ore.*—Cover assay with *aqua regia* in beaker or evaporating dish : heat nearly to boiling point for about twenty minutes —longer if wolfram is present. Dilute with hot water. Filter hot and wash well with hot water, especially if any lead is present in the ore. If there is tungsten or silver in the ore, digest the residue for about ten minutes with warm dilute ammonia ; filter again and wash well the portion on the filter with the same reagent. Dry residue and brush most of residue off the paper. Burn the paper and add the ash to residue.

NOTE.—The solid residue from *aqua regia* consists mainly of silica, stannic oxide, small amounts of iron oxide, various insoluble silicates, and possibly sulphur and insoluble chlorides and oxides produced by the acids used. It is essential to remove here those which will not be removed in subsequent stages of the assay.

If tungsten is present in the sample, probably as wolfram or scheelite, the residue will contain tungstic acid, a yellow solid readily soluble in ammonia. This, if not removed, will count as stannic oxide, giving a high result. Wolfram, even when very finely powdered, is only slowly attacked by *aqua regia*, and time must be allowed for this. After treatment with ammonia, niobic oxide, a white solid derived from columbite, may still remain, but it is unlikely to be present in sufficient quantity to seriously affect results. If its presence is suspected the substance weighed as stannic oxide may be tested for it and also for tantalic oxide.

2. *Reduction of the Stannic Oxide to Tin.*—Heat the assay to dull redness for about forty minutes in an atmosphere of coal gas— $SnO_2 + 2H_2 = Sn + 2H_2O$.

NOTE.—A combustion tube works perfectly although it is inconvenient to manipulate. Poor ores in 5-grm. lots may be placed direct in the tube. Rich ores in 1-grm. lots can be placed in china boats to avoid loss in getting them out of the tube. To place a 5-grm. charge in the tube, it is convenient to have a tin spoon of semi-circular section with a long wire handle. (See accompanying sketch of the apparatus).

Commence passing gas first. When all air has been expelled from the tube, light the jet at its outer end, then warm the tube from end to end, place the Bunsen (a large fish-tail) under the assay and cover the tube with a bent sheet of asbestos to retain the heat. Complete reduction of all the stannic oxide in a large charge may be assisted by slightly turning the tube round once or twice to better expose the lower part of assay to the gas. Carbon is reduced from the gas and darkens the assay, but does not interfere. If any tungsten is present it will be partly reduced if the temperature is high, and will give a high result. Any iron present is reduced, but is removed in filtering after passing H_2S at a latter stage. After reduction is complete extinguish the Bunsen, but leave the gas passing until the assay is cool enough not to re-oxidise on admission of air. Most of the charge can then be

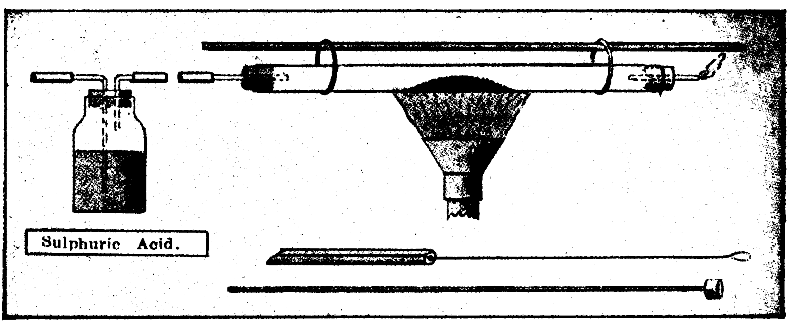


FIG. 37.—TIN ASSAY.
Apparatus used for 5-grm. charge.
(Iron gauze supporting tube and asbestos sheet covering it are not shown.)

poured out of the tube and the remainder cleaned out by a rod with a cork on its end if the sample is poor; or washed out with hydrochloric acid if rich.

3. *Solution of the reduced Tin.*—Transfer assay to a beaker. Cover with strong hydrochloric acid and add about 2 c.c. of a 10% solution of permanganate. Heat nearly to boiling for about twenty minutes, stirring occasionally. Add a few drops of permanganate towards the end. Dilute, filter into a beaker, washing residue well.

NOTE.—In this step all metals present are converted to chlorides, *e.g.*:—$Sn + {}_2HCl = Sn\ Cl_2 + H_2$. Then $Sn\ Cl_2 + Cl_2 = Sn\ Cl_4$.

The chlorine, liberated by the permanganate, assists in the solution of the tin and further converts it to the stannic condition.

4. *Precipitation as Stannic Sulphide.*—Partly neutralize the filtrate by adding sodium bicarbonate cautiously until effervescence becomes less brisk, but the filtrate must remain acid. Pass hydrogen sulphide. The precipitate is stannic sulphide and should be yellow or brownish yellow. Allow assay to stand as long as convenient—overnight if possible—to allow precipitate to settle and clot. Filter on small ashless paper. Wash well with solution of ammonium acetate containing a little free acetic acid. The sodium salts now present should be completely washed out.

NOTE.—As strong hydrochloric acid attacks stannic sulphide, it is better to reduce the acidity as above. The solution must remain acid to keep up metals other than tin. The precipitated sulphide is very finely divided and apt to pass though the filter paper; this is partly counteracted by allowing the precipitate to settle and clot, and also by the sodium chloride produced by the addition of the carbonate.

5. *Conversion of the Stannic Sulphide to Oxide.*—Dry thoroughly the paper containing the precipitate, which will darken considerably. If small in quantity all had better be left on the paper. Holding the paper between a small pair of forceps, burn it as completely as possible and drop the ash into a small weighed Berlin crucible. Add one or two drops of nitric acid and heat gently until dry. Ignite over blow pipe, first gently, then strongly. Cool and weigh as stannic oxide.

NOTE.—The sulphide can be burned to oxide without the addition of nitric acid, but loss may occur, as the sulphide is slightly volatile.

TEST ASSAYS.

For these prepare artificial ores of pure silica and stannic oxide. The former, if ignited, is very hydroscopic, so must be kept in a stoppered bottle. The latter must be tested for purity, and had better be prepared from the purest tinfoil obtainable, by boiling in nitric acid, filtering, and washing with hot water until filtrate gives no precipitate (PbS) with hydrogen sulphide.

A 1% ore and a 0·5% ore should be sufficient, and after a little practice an assayer should be able to get the full tin content out of these samples, but must be on his guard against some of the very finely divided silica passing through the filter.

The hydrogen reduction can be checked by saving the residue and re-igniting in the tube. This should not be omitted where close accuracy is required, and, in ordinary practice, time can be saved by adding the solution thus obtained in stage 3 from the residue to the similar solution already obtained in stage 3 of the assay, and then passing hydrogen sulphide through the combined solutions.

The tendency in most steps of the assay is to get low results, and the manipulation requires time and patience, but the assayer who works on artificial ores of known tin contents until he can trust

himself will be satisfied with the method for the purpose of mine assaying.

Low results arise from incomplete reduction, incomplete solution of the reduced tin, and volatilization of the sulphide by too-hurried ignition. Of these the first is most probable, and an assayer would be wise to at first save the residues from stage 3, re-reduce them in the tube and run them as separate assays, thus determining for himself the probable error due to this cause in the ores of his mine. The greater the proportion of silica present the less complete is the reduction apt to be. In reporting results, it should be borne in mind that "black tin" is impure stannic oxide, the actual tin content varying on different mines.

The last series of assays run by the writer gave the following results, 4 grm. ore being taken for each experiment :—

No.	Stannic Oxide got.		Stannic Oxide recovered from Residues by a Second Reduction in Tube.		Total Percentage.
	Grams.	Percentage.	Grams.	Percentage.	
1	0·230	0·575	0·0020	0·050	0·625
2	0·230	0·575	0·0031	0·077	0·652
3	0 0238	0·595	0·0031	0·077	0·672
4	0·230	0·575	0·0033	0·082	0·657

The residues from Nos. 1 and 2 were reduced a third time in the tube, but only a trace of tin was got.

To illustrate the interference due to wolfram, four charges of 4 grm. each were taken from the above sample ; to each 0·01 grm. taken from a crystal of wolfram was added, and the residue from *aqua regia* was not treated with ammonia, the results being the following :—

No.	Stannic and Tungstic Oxide got.		Recovered from Residues by a Second Reduction in Tube.	
	Grams.	Percentage.	Grams.	Percentage.
1	0·0292	0·730	0·0030	0·075
2	0·0254	0·635	0·0032	0·080
3	0·0262	0·655	Not re-reduced	—
4	0·0270	0·675	Not re-reduced	—

The writer has to thank Mr. J. Caspell, of Camborne Mining School, for valuable suggestions, and Mr. J. C. Montero, Assayer at Dolcoath Mine, for kind assistance with experiments.

The following paper on the assay of tin was read by J. H. Collins before the Institution of Mining and Metallurgy in May 1904 :—*

"For practical purposes on the mine there is no method of assay known which is likely to supersede vanning ; for, although the weight of 'black tin' obtained from a given sample by different operators may vary considerably, the actual quantity of contained metal will be in skilful hands very nearly the same.† For scientific estimations the old École des Mines method of reducing by fusion with KCy and weighing as metallic tin is easy and accurate.‡

"In the assay of 'black tin' by the direct fusion method a previous cleansing by boiling with acid is often recommended, the supposition being that cassiterite is altogether insoluble under such treatment. This, however, is by no means the case ; in fact, I long ago noticed that some varieties of natural peroxide of tin were very freely soluble in HCl when in a fine state of division, and that even when HNO_3 had been added to the HCl, some tin was apt to go into and remain in solution for a considerable time.

"Early in the year 1903 a very distinguished metallurgist wrote me from the United States to the following effect :—

"'You will probably be surprised to learn that native oxide of tin may be dissolved completely in dilute H_2SO_4 in presence of zinc. I presume it is the nascent hydrogen which does the work, but if anyone had suggested to me the possibility of such a method being applicable to native tin oxide, I should have used "strong language" ; but we live to learn.'

"Remembering my previous experiences of the solubility of cassiterite, I believe I mentioned this remarkable statement of my metallurgical friend to some members of this Institution before making any further experiments, but lately I have made a few tests, the results of which seem to me decidedly interesting. I began by taking half a grm. of five different substances § in fine powder, reducing them by KCy in

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* J. H. Collins, "Trans. Inst. Min. and Met.," May 1904.

† See remarks by the author in the discussion of Mr. Mackenzie's paper ("Trans. Inst. Min. Met.," Vol. XIII., p. 94), and also experiments reported by Mr. Richard Pearce (*Eng. and Min. Journal*, p. 117, Jan. 21, 1904).

‡ If lead, bismuth, arsenic, antimony, tungsten or other bases of group 2 are present, proper means must be taken for their elimination before or after the reduction, but many samples of black tin are obviously free from these bases, and may therefore be thus assayed direct. If much silica is present the tin will not readily form one globule. In such cases the whole fusion should be dissolved in hot HCl, and the tin precipitated by H_2S, when the sulphide may be calcined, or reduced before weighing in the ordinary way.

§ No. 1 consisted of clean light-coloured crystals of cassiterite, from Great Wheal Fortune in Breage.

No. 2, closely dressed "black-tin," of a fine brown colour, from Wheal Metal in Breage.

No. 3, reddish-brown wood-tin, from Mexico.

No. 4, greyish-brown wood-tin, from Bolivia.

No. 5, a dark brown mixture of wood-tin and cassiterite crystals, from Wheal Metal.

a porcelain crucible, dissolving the fusion in hot HCl, precipitating by H_2S, igniting the precipitate, and weighing as SnO_2.

"No. 1 was found to contain 99·2 per cent. of peroxide of tin; No. 2, 94·0 per cent.; No. 3, 68·0 per cent.; No. 4, 76·0 per cent.; and No. 5, 94·5 per cent.

"Half a grm. of each sample, in very fine powder, was then placed in a beaker with 20 c.c. of dilute H_2SO_4 (1 to 5), and 2 grm. of pure zinc, and left overnight. The solutions thus obtained were boiled, precipitated with H_2S, the precipitates collected, ignited and weighed, giving quantities of SnO_2 as under:—

No. 1 gave 3 mg. = 0·6 per cent. of soluble (out of 99·2 per cent.).
No. 2 gave 9 mg. = 1·8 per cent. (out of 94·0 per cent.).
No. 3 gave 160 mg. = 32·0 per cent. (out of 68·0 per cent.).
No. 4 gave 360 mg. = 72·0 per cent. (out of 76·0 per cent.).
No. 5 gave 81 mg. = 16·2 per cent. (out of 94·5 per cent.).

Similar treatment with dilute HCl gave very similar results."

New Method to Separate Antimony and Tin.

*The numerous known methods to separate tin and antimony are delicate and complicated. The following process, invented by M. A. Czerwek, is more simple, though as accurate, but not applicable in all cases. Its principle is to dissolve the alloy in a mixture of nitric and tartaric acids at precipitate, at boiling point, the tin by phosphoric acid, all the antimony remaining in solution, Digestion is operated in a hot place with 0·5 gramme of alloy in a solution composed of 15 cubic centimetres of HNO_3 (1·42); 15 of water and about 6 grs. of tartaric acid, all heated to 50 deg. C. After a maximum of 3 hours the solution is complete. Then all is heated briskly until ebullition commences, and while agitating 5 to 30 drops of 45 per cent. phosphoric acid (xd 1·3), according to amount of tin, are added. Dilution is made with 300 cubic centimetres of boiling water, and then the mixture is let deposit in a bain-marie. The clear liquor is then decanted on a filter, the gelatinous precipitate being washed with hot water containing nitrate of ammonia. The precipitate is placed in a beaker-glass, yet humid, and the residue on the filter dissolved with Am_2S hot and all united. The precipitate having been totally dissolved in heating, it is let cool completely, then diluted with a rather large volume of water and Sn precipitated with H_2SO_4. The greenish-grey precipitate is let deposit in a bain-marie, then the liquid is decanted and washed on the nitrated water filter. After drying, the filter is separately incinerated in a tarred crucible, and the precipitate is added; oxidisation is effected with HNO_3 ($d = 1·42$), then evaporation in a bain-marie, calcination, and weighing in form of SnO_2. The filtrate, after separation of Sn, is

* *Echo des Mines*, November 29, 1906.

neutralised with NH_3, mixed with Am_2S, then acidified with acetic acid. The antimony sulphide precipitated is, after deposit in the bain-marie, filtered while hot, washed in nitrated water, and redissolved humid with Am_2S. The liquor is evaporated in a large porcelain crucible, then oxidised with fuming HNO_3, evaporated to dryness, and H_2SO_4 expelled by heating on asbestos. Then the crucible is heated on a non-lighting flame, somewhat sharply finally, and the tetroxide is subsequently weighed. When the alloy contains other metals than Sn and Sb, work is the same. Once the tin precipitated, the precipitate is washed with hot water on a filter, then with 150 to 200 cubic metres of normal nitric acid hot. Residue on the filter is dissolved by Am_2S (or Na_2S in presence of copper), all being united in a beaker glass. After solution the liquor is again filtered on the same filter to retain traces of insoluble sulphides, washing is operated with the diluted solution and precipitation of Sn by H_2SO_4. The filtrate containing Sb and the other metals is then neutralised, mixed with Na_2S or Am_2S, according to cases. After deposit in the bain-marie the precipitated sulphide is filtered and washed. Finally Sb in the filtrate is precipitated with acetic acid.

*Extraction of Tin from Dross.**—According to a patent taken out by H. Brandenburg and A. Weyland,† tin is separated from dross, slag, and waste in the following manner:—The powdered dross is mixed with water, and treated with a mixture of one part of hydrochloric acid with two parts by volume of sulphuric acid, no extraneous heating being needed; and the tin dissolved is separated from the filtered solution by known means. Sodium chloride may replace hydrochloric acid in the process; or the sulphuric acid may be replaced by sodium bisulphate, in which case the mixture will need to be heated.

Treatment of Scrap Tin.—It is reported that there are seven works in Germany operating the electrolytic process for recovering tin from scrap. Sodium hydrate is the electrolyte generally used. There is also one plant in Austria, and one at Manchester, England. About 30,000 tons of scrap are treated annually in Germany, the supply being drawn from England, France, and Switzerland, besides from domestic sources.

C. D. Brindley ‡ has patented a process for recovering tin from scrap, which consists in heating the scrap in an oven upon stepped, inclined, and perforated plates, to which a jigging movement is imparted by suitable machinery. In passing down the steps the solder melts and flows through the perforations, and is collected from below. At the bottom of the steps the scrap passes into a hopper, and thence into a chamber, in which it is cut into strips by an arrangement of mechanically-worked steel blades. After cleansing and dissolving off the tin

* "The Mining Industry," 1903.
† English Patent, No. 16,377, July 24, 1903.
‡ English Patent, No. 8,693, April 15, 1902.

or zinc coating by a suitable acid, the shearings are moistened with a solution of an acid or mineral salt and exposed in heaps to the air. When oxidised the mass is ground, and the ferric hydroxide is calcined to form a pigment.

The Alkali Act of 1892 applies to tin mines where ores containing arsenic are being roasted; the exact proportion of arsenical fumes that may be given off depends on circumstances. The Act is administered by inspectors under the Local Government Board.

CHAPTER XX.

STATISTICS OF TIN PRODUCTION.

TIN mining must continue to be a progressive industry to keep up with the demand for the metal. Very few new tinfields of any magnitude have been discovered in the last ten years, whilst the easily-worked alluvial deposits are everywhere being rapidly depleted, and what is left is costing more to win; consequently, unless large and unforeseen discoveries are made in Africa, north of the Malay Peninsula, or elsewhere, there seems a reasonable chance of tin maintaining its present price, with a tendency to increase.

It has been stated that high prices must react unfavourably upon the uses of tin, but the experience of the last few years has disproved that idea, as the markets have (at the higher price of the metal) shown that its consumption is quite equal to the increase of output. One reason of this may be found in the fact that the great variety of manufactures into the production of which tin enters to some small degree, but which aggregate the great bulk of the consumption, are consequently much less adversely affected by high prices than any individual industry the product of which requires any considerable amount of the metal, and this broadening of the field of industrial application is a most satisfactory feature. Furthermore, tin once used is rarely recoverable in any large quantity, and is therefore a wasting commodity.

Various patented processes are in operation for the recovery of tin from scraps, the most important works being situated in Germany, and America; and although it is impossible to get exact figures, the recovery at present is a slow and costly one—but the cheapening of these methods may lead in future to a new and disturbing element in the tin market.

The treatment of new tin scrap, known as "detinning," has become of considerable importance in the United States, and at least ten companies were actively engaged in this special branch of the industry during the year 1906. The average yield from tin scrap is approximately two per cent. of metallic tin. In addition, a large number of small concerns in the principal cities recover the tin from old tin cans and similar material by a smelting treatment in a furnace, the tin being obtained in the form of solder, which is either used as a basis for making new solder, or is treated chemically to yield metallic tin or tin

salts. The residue of scrap iron is generally utilized in the manufacture of sash weights and other castings of inferior quality of iron.

The factor that must control the tin market to a very large extent is the price at which it pays the tin mines of the Malay Peninsula to continue producing the metal, and that at present is computed to be £160 a ton for metallic tin.

Lode mining in the Malay Peninsula may be regarded as in its infancy, and many years must elapse before the output from this source can become a factor in the tin market.

With regard to the new tinfields lately discovered in Africa and Alaska, it is too early to make a correct forecast of their future, but from the reports furnished of the size and nature of these deposits, it seems, in the opinion of the writer, a safe deduction to make, that many years must elapse before these fields can become a real factor in the tin market; and although it is proverbially unsafe to prophesy, still the inference to be drawn is that the price of tin cannot fall much below £160 a ton, and it is felt that this inference is a fair and safe one, as very little below that market price would cause many mines to close down, and thus materially decrease the output.

The rise in price has also caused a search for a substitute for tin in the manufactures. The possible use of such substitutes is well summed up by L. Parry* in an excellent article, from which the following quotations are made:—

"The diminution in the price of aluminum, the practically limitless supply of raw material, and the physical properties of the metal are facts which must at once appeal to the technical imagination, and point to this—the most abundant of the metallic elements—as a possible substitute for tin. At the same time it is not the only metal which has to be considered in this connection.

"The world's annual production of tin is now about 91,000 tons (long), and the principal uses to which the metal is applied are as follows:

"A, The manufacture of tin plates. Tin plate holds from 2 to 3 per cent. of tin. Two samples recently assayed by the writer contained 2·65 per cent. (thin piece) and 3 per cent. (thick piece), respectively. The tin-plate production of South Wales is probably about 12,000,000 to 13,000,000 boxes, and that of the United States of America about the same. Germany is probably the next largest producer, with about 1,000,000 boxes, or, say, 1,350,000 tons, for the world's production. The tin in tin-plate is stated on good authority to run about 2¼ pounds per hundredweight on output, or about 2 per cent., which means that about 27,000 tons of metal are consumed for this purpose.

"B. The manufacture of machine bronzes and brasses, which in all probability accounts for the greater proportion of the world's consumption.

"C. The manufacture of various white alloys, such as solder, type

* Substitutes for tin: "Mining Journal," London. vol. 79, June 2 1906, p. 728.

metal, pewter, Britannia metal, white bearing metals, to mention the more important. Of these we would particularly direct attention to the ever-increasing consumption of white bearing metals, or so-called anti-friction metals, which contain all percentages of tin up to 90 per cent., and which, we might incidentally add, all hold 5 to 20 per cent. antimony as an essential constituent—a point which may have some bearing on the increased price of antimony. Of other white alloys we have capsule metal, tea lead, tinfoil, electric fuse metal, accumulation metal, metallic packing, fusible alloys, and the various white alloys holding tin which are used for making ornaments and toys.

"D. Ornamental bronzes and gold and silver-plated white metals.

"E. Tin crystals, tin oxide, etc. A considerable amount of stannous chloride (tin crystals) is consumed in various branches of textile industry. Tin oxide is the principal constituent of many polishing powders.

"A. With regard to tin-plate there is very little doubt that many of the uses to which it is applied could be quite well fulfilled by aluminum or galvanized iron, or, assuming the manufacture of such a material to be a practicable proposition, by aluminum plate—that is, iron coated with aluminum. The price of aluminum is now about that of tin and about fourteen times that of tin-plate, and as the specific gravity of aluminum is, roughly, one-third that of tin plate, the cost of aluminum sheet would be about four and a-half times ($\frac{1}{3} \times 14$) that of tin plate of the same thickness. A rise in the price of tin does not, of course, affect very greatly the price of tin plate; thus on January 6 tin plates 20 by 14 were quoted at 13s. 3d. per box, and on May 19 at 14s., an increase of 9d. per hundredweight, or 15s. £0·75 per ton. We should note that the price of steel bars had meanwhile dropped from £5 5s. to £5. The price of tin on January 6 was £163, and on May 19 £194, an increase of about £30 a ton. If we assume, for the sake of argument, that there is 3 per cent. of tin in tin plate, the increased cost of producing plates would be 3 per cent. by £30—£·9 per ton, which agrees pretty closely with the actual increase. An increase of £33 in the price of tin means an increase in the cost of producing plates £1 per ton, or 1s. only per hundredweight. It is obvious from these figures that a very large increase in the price of tin can have practically no influence in diminishing the relative cost of aluminum sheet as against that of tin plate; with aluminum and tin at the same price, there is a margin of £50 or £60 between the cost of equal bulks of the two materials. Thus before aluminum sheet can hope to compete with tin plate in the matter of price, one or both of two things must happen—namely (a), an undreamt-of increase in the price of tin, (b) a considerable lowering in the price of aluminum—a point to which very considerable attention is being paid—the matter is very different; the cost of tin and aluminum being about the same, there might easily be very little difference in the cost of producing the two kinds of plate, and that difference might, as far as we know, be on either one side or the other, though it would seem probable that the cost of producing aluminum plate would necessarily be greater, owing

to the higher melting point of aluminum and its ready oxidizability. However, a rise of £20 or £30 a ton in the price of tin might then be sufficient to turn the scale in favour of aluminum plate, other things being the same. As is well known, aluminum is sufficiently tenacious and malleable to replace tin plate, resists atmospheric influences well, and, whether as plate or sheet, could be employed in the manufacture of many domestic utensils and vessels used for containing food stuffs, tobacco, etc. There cannot be much objection (apart, of course, from cost) to its use in the case of such things as tea, coffee, cocoa, biscuits, tobacco; but in the case of preserved fruits, meat, and vegetables the objection has been made that aluminum is attacked by organic acids. This is a very important point, and one upon which there is much conflict of opinion. It would seem that the liability of aluminum to attack by fruit acids depend largely on its purity. In any case, we must remember that the aluminum industry is in its infancy, that the power of resistance of the metal to organic acids is a matter which requires investigating, and that we can scarcely condemn its use in such connection on the strength of the scanty knowledge we possess.

"B. Machine bronzes and brasses may contain up to 5 per cent. tin, according to the purposes for which they are required. As the world's annual output of copper is now about 800,000 tons, and that a very large proportion of this is employed in the manufacture of machine bronzes and brasses, we see at once that this must mean a correspondingly large consumption of tin. Many of the essential physical properties of tin-copper or tin-copper-zinc alloys may be obtained by the partial or complete substitution of tin by aluminum, manganese, nickel, or iron, though it would, perhaps, be incorrect to say that such an effect could always be produced, or that such alloys would be invariably cheaper. The object of successful brass founding is the production of a suitable alloy at a profit. If, for instance, the price of tin, aluminum, and nickel happened to be about the same, and it was found possible to obtain the properties required in a gun metal holding 90 of copper and 10 of tin by adding 1 or 2 per cent. each of aluminum, nickel, and tin to a copper-zinc base, it would certainly pay to do so. A rise in the price of tin should stimulate research in the direction of such combinations. It is an unfortunate fact, however, that the English brass founder is disinclined to spend money on trained technical research, as he has not yet discovered that it would pay him to do so. A large brass founder (English, of course) once expressed to the writer his opinion that a chemical laboratory was a waste of money in a foundry.

"The aluminum bronzes and brasses are a most important class of alloys, and will be produced in much larger quantities as the price of tin increases, or that of aluminum declines.

"C. Of the important white metals we may say at once that solder and type are required on account of such special and definite combinations of physical properties that their replacement by other metals to any appreciable extent is quite improbable. With regard to white bearing metals, again the tin which is used in their manufacture confers

physical properties upon them which can scarcely be otherwise obtained, so that the consumption of tin in their manufacture is likely to increase rather than to diminish.

"D. With regard to ornamental bronzes it is difficult to speak with any degree of certainty. The use of tin, however, is not an absolute necessity, and its consumption for the purpose has been diminishing for some time. On the other hand, an increased amount of tin is probably now used in the manufacture of white-metal ornaments—*e.g.*, in the case of white bronzes.

"Many white-metal combinations are employed in making ornaments, and it is probable that the demand with regard to quality readily accommodates itself to the supply. The quality of such goods probably varies far more than the price. If tin keeps up in price for a year or two it will probably be found that the percentage of tin in white-metal ornaments will diminish considerably. With regard to white metals used as bases for electro-plating with gold and silver, it has already been found possible to use aluminum. The processes are still in their infancy, but no doubt the use of aluminum for this purpose will become more and more common."

The past year of 1906 has been a record one for tin, whether from the point of view of production, price, or interest. At the same time, there have been no new developments of any importance during the year, and the general position appears similar to that at the end of 1905. Perhaps the most noticeable feature of the year is the decline in the production of the Federated Malay States, in spite of the much higher price averaged during the year, £180 12s. 9d. against £143 2s. 1d. per ton. In the Straits the price averaged about 19 dollars a pikul better, as compared with a rise of a little over 4 dollars during 1905.

In the Dutch Indies the sales from Banca decreased from 9,960 tons in 1905 to 9,298 tons in 1906. Production may have reached 11,000 tons. Of Billiton there is not very much information. The sales during the past year were reported at about 1,950 tons.

In Siam there is not much increase, and in regard to Siamese Malaya probably the same causes which are operating to keep down the output of the Federated Malay States will be experienced higher up the country.

The next most important source of production is South America. The Bolivian yield has been variously estimated. Dealing only with exports they show that the ore exported amounted to 17,627 tons, which at 60 per cent. gives us 10,574 tons of metal against 15,139 tons ore, equal to 9,083 tons metal last year. The metal imports from Bolivia are not shown separately, but as shipments other than those from the Straits and Australia, of which in past years Bolivia has claimed about half, show an increase of only 600 tons, 1,700 tons will probably cover Bolivian metal shipments to England; thus the total would be some 12,274 tons to this country. The "Monatliche Nachweise uber den Auswartigen Handel Deutschlands" shows no shipments to Germany from South America from March to November. On the other hand, the imports of tin-ore amounted to no less than 13,000 tons,

which yielded 8,000 tons of pure metallic tin, and the exports of tin from Germany amounted to 4,320, against 2,940 in 1905.

Australia has undoubtedly had a good year. The latest Government figures I have been able to obtain by the courtesy of the various Agents-General are the following, calculated from values given at £180 a ton :—

New South Wales (9 months),	1906 - - -	1,256 tons.
Queensland (9 months)	„ - - -	1,985 „
Tasmania (6 months)	„ - - -	1,357 „
West Australia (8 months)	„ - - -	512 „

Averaging the remaining months on previous yield, the returns would be :—

	1906.	1905.
New South Wales - -	1,675 tons.	1,215 tons.
Queensland - - -	2,647 „	2,080 „
Tasmania - - - -	2,714 „	2,536 „
West Australia - - -	768 „	607 „
	7,804 tons.	6,438 tons.

These figures are, of course, far from exact, but, as will be seen, they give an increase of nearly 1,400 tons. Finally there are the increased shipments from other countries, amounting to some 300 tons as metal and 750 tons as ore. Of this amount, however, probably at least half has been already included under Australia. We may allow, therefore, 600 tons under this head. The result works out, therefore :—

Increase.		Decrease.	
Banca - -	2,350	Malay States - -	2,370
Billiton - -	500		
Bolivia - -	2,000		
Australia - -	1,400		
Sundries - -	600		
Total Increase	6,850		
„ Decrease	2,370		
Increase - -	4,480		

That is to say, that last year production increased about 4,500 tons. Taking the output in 1905 at 90,000 tons, the increase was $5\frac{1}{2}$ per cent. The average increase in the production of tin from 1884 to 1903 was 5·11 per cent., so that the above result seems quite normal. On the other hand, consumption last year was no doubt exceptional, as the year was a record in the consumption of iron, copper, etc., to the use of which tin bears a fairly constant proportion. Under the circumstances, therefore, I can see nothing abnormal in the present prices, and, short of a great decline in business, would expect to see something of the kind averaging for the year ; though, of course, serious labour scarcity in the East or Bolivia might cause trouble. On the whole, supplies are on a good broad basis, adverse to marked fluctuations.

Economies in the use of tin are not unlikely to be introduced, and it is expected that the quantity required during 1907 will be probably over 36,000 tons for America. European consumption may be expected to increase, after having been stationary for some time, and thus the course of prices would seem to depend very much upon the quantity to be produced in the Straits Settlements.

The consumption of tin produced is approximately as follows; this is compiled from official returns:—

United States - -	Taking	40·6	per cent. of output.
Great Britain - -	,,	16·8	,,
Germany - - -	,,	15·7	,,
France, Italy, Spain, Russia	,,	18·9	,,
Eastern Europe and South America	,,	4·5	,,
Eastern Asia - - -	,,	3·5	,,
Total consumption - - -		100·0	

Comparative Table Showing the Total Visible Supply of Tin at the End of Each Month.

In Long Tons.

—	1906.	1905.	1904.	1903.	1902.
January - - -	15,115	15,645	17,115	17,679	18,351
February - -	14,261	14,911	16,450	16,294	17,043
March - - -	12,748	14,592	15,662	19,497	18,131
April - - -	11,959	13,063	13,695	15,978	15,596
May - - -	13,520	12,967	14,609	16,463	17,018
June - - -	12,590	11,938	13,780	15,107	15,897
July - - -	13,013	12,270	13,818	16,507	16,809
August - - -	12,295	12,572	12,480	16,544	16,293
September - -	13,235	14,508	13,159	17,249	18,025
October - - -	11,778	12,812	12,194	15,515	16,053
November - -	12,825	13,174	14,412	15,195	18,346
December - -	13,320	13,451	14,768	14,274	16,769

STATISTICS OF TIN.*

—	30th Nov. 1906.	31st Dec. 1906.	30th Dec. 1905.	31st Dec. 1904.
	Tons.	Tons.	Tons.	Tons.
Straits and Australian, spot	1,104	1,506	2.266	3.498
" " landing and in transit	232	975	1,184	1,588
Straits, afloat	3,100	3,500	3,550	3,225
Australian, afloat	749	733	890	756
	5,185	6,714	7,890	9,067
Banca, on Warrants	1,557	794	962	767
Billiton, spot	—	—	43	10
" afloat	183	183	180	270
Straits, spot in Holland	364	182	455	100
" afloat to Continent	725	520	700	800
	8,014	8,393	10,230	11,014
Total afloat for United States	3,350	3,085	2,875	3,425
Estimated Stock in America	1,461	1,842	501	959
Total	12,825	13,320	13,606	15,398
Prices of Straits and Australian	£197 10*s.*	£193 10*s.*	£160 10*s.*	£134 5*s.*
Deliveries during the month, in London	1,281	897	726	805
" " " Holland	736	968	894	1,195
	2,017	1,865	1,620	2,000

Shipments the month Dec. 1906 from Straits to London	3,600 tons.	
" " " Straits to America	1,135 "	
" " " Straits to Continent	515 "	
		5,250 tons.
" " " Australia to London		725 "
" " " London and Holland to America		1,781 "

—	During 12 months ending 31st Dec. 1906.	During 12 months ending 30th Dec. 1905.	During 12 months ending 31st Dec. 1904.	During 12 months ending 31st Dec. 1903.	During 12 months ending 31st Dec. 1902.
Shipments from Straits to London	36,110	33,773	35,840	28,710	28,925
" " Straits to Continent	7,563	8,151	7,346	6,448	6,840
" " Straits to America	13,553	15,135	14,444	17,013	16,225
" " Straits to Europe and America	57,226	57,059	57,630	52,171	51,990
" " Australia to London	5,361	4,466	4,248	4,157	3,156
" " Australia to America, &c.	1,311	856	—	—	50
Deliveries of Tin in London	14,484	14,876	14,127	15,301	14,806
" " London and Holland	26,988	28,726	30,271	30,420	30,944
" " America	37,700	37,700	35,900	37,500	36,930
" " London, Holland, France & U.S.	74,614	76,420	75,411	76,156	77,045
Average Price Straits Tin for Cash	£180 12*s.* 9*d.*	£143 2*s.* 1*d.*	£126 13*s.* 11*d.*	£127 4*s.* 1*d.*	£120 14*s.* 7*d.*

Banca in Trading Company's hands, 1,371 tons.

PRICES:	£ *s.* *d.*		£ *s.* *d.*
Straits and Australian spot	193 10 0	Three months	194 10 0 per ton.
English Common ingots	194 0 0	Refined	197 0 0 "
Banca	195 0 0	Billiton	— "

SUPPLY.	DECEMBER, 1906.	CONSUMPTION.	
Straits	5,250 tons.	London Deliveries	897 tons.
Australian	725 "	Dutch	968 "
Billiton	183 "	American	2,800 "
Banca	"	Straits, Continental Ports	815 "
		Billiton	183 "
	6,158 "		5,663 "

Messrs. RICARD & FREIWALD give the VISIBLE SUPPLY of Tin on 31st December as 13,118 tons, against 12,807 tons on 30th November, and 13,501 tons a year ago. SUPPLIES for the month total 6,064 tons, against 6,855 tons for November, and 5,554 tons a year ago. DELIVERIES for same period were 5,753 tons, as against 5,942 tons for November, and 4,990 tons last year. BANCA and/or BILLITON SALES for the month were: Billiton, 184 tons, as against 1,769 for November, and 124 tons a year ago. Banca in Trading Company's hands December 1906, 1,350 tons; December 1905, 1,432 tons.

* "Mining Journal," January, 1907.

Tin Production of Bolivia.*

The amount of tin exported from Bolivia during the year 1904 was as follows :—

	Quantity.	
La Paz	13,427·99	Quintals.†
Oruro	260,174·11	"
Potosi	120,894·65	"
Uyuni	17,126·95	"
Colquechaca	23,735·90	"
Tupiza	20,620·07	"
Total	455,979·67	"

Representing an official value of £1,275,944.

Export of Tin for the First Six Months of 1906.

Customs Houses.	Kilos.	Value.	Duty.
		Bs.	Bs.
La Paz	639,764·32	639,764·32	32,188·98
Oruru	8,502,055·34	8,502,055·34	412,548·76
Uyuni	814,291·08	814,291·08	41,534·69
Tupiza	1,910,104·00	1,910,104·00	92,304·25
Recaudadora de Potosi	3,751,399·82	3,751,399·82	170,606·98
Recaudadora de Colquechaca	335,894·30	335,894·30	16,101·08
Total	15,953,508·86	15,953,508·86	765,284·74

The average of Straits tin, which governs the price in Europe, was for the first six months of the present year £173 10*s.* per tonne, which corresponds for Bolivian ores averaging 60 per cent. to £98 10*s.* per tonne. Taking exchange at ⅟₈, and deducting expenses in Europe, there is a net yield of one boliviano per kilo.—[Signed] V. Tarfon, Inspector-General of Customs Houses, La Paz, 3rd June, 1906.

Production of Tin in Bolivia.‡

Year.	Barilla. Metric Cwts. of 100 kilos.		Metallic Tin.	Official Value in Bolivia.
		Tons.	Tons.	Bs.
1897	37,495	= 3,691	2,215	2,986,500.00
1898	43,960	= 4,327	2,596	3,405,000.00
1899	92,794	= 9,134	5,480	5,730,950.00
1900	162,342	= 15,088	9,053	8,579,539.00
1901	219,159	= 21,573	12,943	9,380,714.00
1902	176,088	= 17,340	10,404	8,782,703.00
1903	221,314	= 21,785	13,071	11,830,073.87
1904	206,919	= 20,369	12,221	9,191,701.51
1905	269,120	= 26,490	15.894	13,180,614.00
1906 (approx.) ...	284,444	= 28,000	16,800	34,490,000.00

Output of Barrilla or Tin Concentrates in Bolivia in 1905, by Districts.§

	Long tons.
Oruro	15,180
Chorolque Potosi, January-June	3,500
Huanuni	460
Panza	200
Total	19,340

* From Mr. Consul Harrison's Report, dated La Paz, March 22, 1905, *vide Mining Journal*, June 10, 1905, p. 627.

† Of 100 lbs.

‡ "Mining Journal," April 20, 1907, p. 543.

§ The exports are given by Mr. C. Mayer as 13,328 short tons for each year. Mr. J. Ramsay Smith, British Vice-Consul at Oruro, gives the above figures of production of tin in Bolivia for 1905.

Tin Exports of Federated Malay States.

States.	1901.	1902.	1903.
Perak	385,060	405,870	436,296
Selangor	302,570	278,360	284,592
Negri-Sembilan	75,230	73,520	85,461
Penang	26,310	23,120	25,317
Total Piculs	789,170	780,870	831,666
Metric Tons	47,713	47,211	50,254

—	1904.	1905.	1906.
	Pikul.*	Pikul.*	
† Perak	450,670	446,782	435,909
Selangor	304,701	289,867	268,624
Negri Sembilan	85,688	85,133	77,766
Pahang	28,068	34,879	34,488
Total	869,127	856,661	816,786
	‡ 57,942	‡ 57,111	‡48,618
Metric Tons	51,790	51,793	—

Federated Malay States Tin Output in Pikuls.

—	1906.	1905.	1904.
	Pikuls.	Pikuls.	Pikuls.
January	71,332	84,245	72,816
February	57,425	56,718	63,009
March	64,999	71,579	63,591
April	68,073	62,975	63,473
May	77,872	71,514	64,106
June	65,216	73,035	71,422
July	65,247	77,085	71,949
August	73.919	74,106	83,427
September	66,281	65,958	78,105
October	75,121	71,203	75,878
November	67,514	70,661	78,217
December	65,774	78,606	76,282
Total, 12 months	816,786	856,660	869,128

* Pikuls: pikul = 133⅓ pounds.
† "Mining Journal" (London), Vol. 79, No. 3682, March 17, 1906, p. 352.
‡ Short tons.

Monthly Returns from Straits Settlements.*

—	1901	1902	1903	1904	1905	1906
January - - -	3,825	4,035	4,740	4,950	5,233	5,998
February - - -	3,980	4,315	3,440	4,716	4,527	4,399
March - - -	3,900	4,645	5,395	3,476	4,169	3,860
April - - - -	4,250	3,995	3,220	5,450	4,613	4,898
May - - - -	4,170	4,160	5,470	4,805	4,661	5,299
June - - - -	4,320	4,970	4,345	5,138	5,078	4,623
July - - - -	4,160	3,670	4,660	4,442	4,158	4,636
August - - -	4,490	5,180	5,160	4,732	5,752	4,965
September - - -	4,580	4,830	4,465	4,319	4,993	4,126
October - - -	3,810	3,835	4,140	4,993	3,915	5,210
November - - -	4,820	4,340	3,760	5,400	4,933	4,982
December - - -	4,100	3,770	3,190	5,142	4,897	4,218

Tin Production of Tasmania.

Return showing the Quantity and Value of Tin exported from Tasmania during the years 1880, 1881, 1882, 1883, 1884, 1885, 1886, 1887, 1888, 1889, 1890, 1891, 1892, 1893, 1894, 1895, 1896, 1897, 1898, 1899, 1900, 1901, 1902, 1903, 1904 and 1905, compiled from Customs Returns only.

Year.	Quantity.	Value.
	Tons.	£
1880 - - - - -	3954	341,736
1881 - - -	4124	375,775
1882 - - - - -	3670	361,046
1883 - - - - -	4122	376,446
1884 - - - - -	3707	301,423
1885 - - - - -	4242	357,587
1886 - - - - -	3776	363,364
1887 - - - - -	3607½	409,853
1888 - - - - -	3775¼	426,321
1889 - - - - -	3764	344,941
1890 - - - - -	3209¼	296,368
1891 - - - - -	3235	291,715
1892 - - - - -	3174	290,083
1893 - - - - -	3128½	260,219
1894 - - - - -	2934	198,298
1895 - - -	2726¾	167,461
1896 - - - - -	2700	159,036
1897 - - - - -	2423½	149,994
1898 - - -	1972	142,046
1899 - - - - -	2239¼	278,323
1900 - - - - -	2029	269,853
1901 - - - - -	1789½	212,542
1902 - - - - -	1958¼	237,828
1903 - - -	$2376\frac{3}{20}$	300,098
1904 - - - - -	2171	255,228
1905 - - - -	3891½	362,670
	$11,499\frac{8}{20}$	7,530,234

* Returns in tons of 2,240 lbs.

Tin Production of New South Wales.

The following Table shows the quantity and value of Tin exported from this State since the opening of the Tin Fields in 1872 to the end of 1903:—

Year.	Ingots. Quantity.		Ingots. Value.			Ore. Quantity.		Ore. Value.			Total Value.		
	Tons	Cwt.	£	s.	d.	Tons.	Cwt.	£	s.	d.	£	s.	d.
1872	47	0	6,482	0	0	849	0	41,337	0	0	47,819	0	0
1873	911	0	107,795	0	0	3,660	0	226,641	0	0	334,436	0	0
1874	4,101	0	366,189	0	0	2,118	0	118,133	0	0	484,322	0	0
1875	6,058	0	475,168	0	0	2,022	0	86,143	0	0	561,311	0	0
1876	5,449	0	379,318	0	0	1,509	0	60,320	0	0	439,638	0	0
1877	7,230	0	477,952	0	0	824	0	30,588	0	0	508,540	0	0
1878	6,085	0	362,072	0	0	1,125	0	33,750	0	0	395,822	0	0
1879	5,107	2	343,075	0	0	813	15	29,274	0	0	372,349	0	C
1880	5,476	6	440,615	0	0	682	6	30,722	0	0	471,337	0	0
1881	7,590	17½	686,511	0	0	609	6	37,492	0	0	724,003	0	0
1882	8,059	0	800,571	0	0	611	0	32,890	0	0	833,461	0	0
1883	8,680	1	802,867	0	0	445	4	21,685	0	0	824,552	0	0
1884	6,315	16	506,726	0	0	349	13	14,861	0	0	521,587	0	0
1885	4,657	18	390,458	0	0	534	18	25,168	0	0	415,626	0	0
1886	4,640	18	449,303	0	0	326	18	18,350	0	0	467,653	0	0
1887	4,669	8	509,009	0	0	291	13	16,411	0	0	525,420	0	0
1888	4,562	2	569,182	0	0	247	8	13,314	0	0	582,496	0	0
1889	4,408	13	403,111	0	0	241	15	12,060	0	0	415,171	0	0
1890	3,409	11	317,117	0	0	259	4	12,724	0	0	329,841	0	0
1891	2,941	5½	261,769	0	0	203	5	9,643	0	0	271,412	0	0
1892	3,253	0	301,541	0	0	239	2	12,573	0	0	314,114	0	0
1893	2,636	17	223,139	0	0	148	1	6,604	0	0	229,743	0	0
1894	2,611	5	179,445	0	0	190	7	7,752	0	0	187,197	0	0
1895	2,199	11	136,080	0	0	77	4	2,543	0	0	138,623	0	0
1896	1,710	4	99,212	0	0	96	19	2.905	0	0	102,117	0	0
1897	1,140	13	70,128	0	0	14	2	560	0	0	70,688	0	0
1898	893	17	60,565	0	0	1	4	35	0	0	60,600	0	0
1899	821	15	98,138	0	0	4	15	290	0	0	98,428	0	0
1900	901	5	120,032	0	0	15	2	900	0	0	120,932	0	0
1901	656	8	76,851	0	0	10	17	464	0	0	77,315	0	0
1902	445	6	52,636	0	0	22	19	1,070	0	0	53,706	0	0
1903	751	19	95 463	0	0	546	14	29,430	0	0	124,893	0	0
1904	1,067	17	130,881	0	0	626	4	49,496	0	0	188,377	0	0
1905	804	6	112,155	0	0	714	14	61,640	0	0	173,806	0	0
Totals	71,008	2	6,386,229	0	0	20,503	13	1,050,232	0	0	7,436,461	0	0

Includes tin refined from imported ores to the end of 1898.
New South Wales Government Report on Mining Industry.

The Production of Tin in Western Australia.

Year.	Tin Ore Exported.			Estimated Value.			Year.	Tin Ore Exported.			Estimated Value.		
	Tons.	Cwts.	Qrs.	£	s.	d.		Tons.	Cwts.	Qrs.	£	s.	d.
1889	5	0	0	300	0	0	1899	335	0	0	25,270	0	0
1890	67	10	0	5,400	0	0	1900	823	0	0	56,702	0	0
1891	204	0	0	10,300	0	0	1901	734	0	0	40,000	0	0
1892	265	9	3	13,843	0	0	1902	620	0	0	37,783	0	0
1893	227	19	0	11,134	0	0	1903	817	0	0	55,890	0	0
1894	390	5	0	15,274	0	0	1904	854	0	0	58,817	0	0
1895	277	3	0	9,703	0	0	1905	1,079	0	0	86,840	0	0
1896	137	5	0	4,338	0	0							
1897	95	11	0	3,275	0	0							
1898	68	2	3	2,760	0	0	Total	6,928	7	8	433,829	0	0

Tin Production of Queensland.

	Tin Ore.			Tin Ore.	
	Tons.	Value.		Tons.	Value.
1872 -	1,407	109,816	1890 -	2,970	154,963
1873 -	8,938	606,184	1891 -	2,236	116,387
1874 -	5,702	358,550	1892 -	2,389	123,098
1875 -	4,475	237,879	1893 -	2,434	106,953
1876 -	4,315	187,201	1894 -	2,871	102,277
1877 -	3.335	133,432	1895 -	2,114	68,133
1878 -	2,849	88,366	1896 -	1,554	49,018
1879 -	2,877	120,391	1897 -	1,203	37,509
1880 -	2,847	142,977	1898 -	1,025	36,502
1881 -	3,456	193,699	1899 -	1,308	77,302
1882 -	4,261	269.904	1900 -	1.123	74,041
1883 -	3,346	187,292	1901 -	1,661	93,723
1884 -	3,383	130,460	1902 -	2,085	116,171
1885 -	3,253	151,871	1903 -	3,708½	243,149
1886 -	3,153	162,124	1904 -	3,923	270,276
1887 -	3,279	217,389	1905 -	3,945	297,454
1888 -	3,586	200,019			
1889 -	3,033	156,406	Total -	104,044½	5,620,916

* Output and Value of Tin Ore (“*Black Tin*”) in the United Kingdom from the Year 1873 to 1905.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Tons.	£		Tons.	£
1873 -	14,885	1,056,835	1890 -	14,911	782,492
1874 -	14,039	788,310	1891 -	14,488	735,240
1875 -	13,995	735,606	1892 -	14,357	734,565
1876 -	13,688	600,923	1893 -	13,689	637,053
1877 -	14,142	572,763	1894 -	12,910	487,523
1878 -	15,045	530,737	1895 -	10,612	370,530
1879 -	14,665	586,608	1896 -	7,663	259,928
1880 -	13,738	673,142	1897 -	7,120	254,218
1881 -	12,898	697,444	1898 -	7,380	288,325
1882 -	14,045	805,847	1899 -	6,392	440,509
1883 -	14,469	735,189	1900 -	6,800	523,604
1884 -	15,117	669,254	1901 -	7,288	478,559
1885 -	14,376	662,390	1902 -	7,560	513,872
1886 -	14,232	780,302	1903 -	7,382	532,450
1887 -	14,189	878,831	1904 -	6,742	479,633
1888 -	14,370	894,665	1905 -	7,201	574,183
1889 -	13,809	729,213			

* Government Mines Report, 1905.

Tin Production of Banca.*

	Tons.
1900–1901 - - - - -	12,335
1901–1902 - - - - -	10,400
1902–1903 - - - - -	10,400
1903–1904 - - - - -	12,438
1904–1905 - - - - -	7,700
1905–1906 - - - - -	8,832

The quantity of Banca tin sold and the average price per 50 kilos at the six bi-monthly sales during 1905 was as follows :—

—	Slabs.	† Tons.	Average Price.
			Florins.
January sale - -	57,400	1,979	79
March „ - -	46,500	1,603	83¼
May „ - -	47,183	1,627	83¼
July „ - -	45,995	1,586	90⅞
September „ - -	45,987	1,586	88⅞
November „ - -	45,802	1,579	96⅛
Total - -	—	9,960	—

Tin Production of Billiton.

—	Tons.	—	Tons.
1896–1897 - -	4,479	1901–1902 - -	4,661
1897–1898 - -	5,266	1902–1903 - -	4,484
1898–1899 - -	5,406	1903–1904 - -	3,870
1899–1900 - -	4,762	1904–1905 - -	4,218
1900–1901 - -	4,479	1905–1906 - -	4,462

* Official estimate.

† Official estimate long ton of 2,240 lbs. given.

Exports of Tin from the United Kingdom in the Years 1905–1906.*

(Return by Board of Customs.)

Countries to which Exported.	British.†		Foreign.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Russia:				
Northern Ports	898	126,585	675	95,972
Southern Ports	500	67,842	121	17,227
Sweden	401	55,642	4	590
Norway	119	16,497	—	—
Denmark	78	10,858	33	4,425
Germany	344	47,927	1,609	224,724
Netherlands	141	20,028	4,242	608,582
Belgium	126	17,376	46	5,278
France	758	105,643	110	15,357
Portugal, Azores, and Madeira	398	55,098	11	1,483
Spain and the Canaries	487	68,826	377	53,516
Italy	95	13,127	26	3,489
Austria-Hungary	97	13,941	33	4,124
Greece	44	6,225	—	—
Bulgaria	45	6,546	—	—
Roumania	25	3,576	—	—
Turkey:				
European	108	15,550	5	700
Asiatic	132	19,203	2	154
Egypt	215	31,036	—	—
British Possessions in S. Africa	93	12,984	—	—
East Coast of Africa	7	760	—	—
British East Indies	170	22,986	—	—
China	11	1,531	—	—
New Zealand	13	1,745	—	—
British North America	440	61,143	—	—
United States of America:				
On the Atlantic	1,287	171,936	21,802	3,076,718
British West India Islands and British Guiana	5	802	—	—
Foreign West Indies	20	2,809	—	—
Mexico	16	2,126	—	—
Peru	10	1,384	—	—
Chili	56	7,853	—	—
Brazil	137	19,171	3	458
Uruguay	26	3,611	48	6,391
Argentine Republic	287	40,238	7	1,014
Other Parts	34	5,265	1	183
Total Exports in 1905	7,623	1,057,780	29,155	4,120,385
Total in Preceding Year	5,864	741,847	27,225	3,430,280

* Government Mines Statistics, 1906.

† The figures under this heading include tin which had been imported from abroad, but which was refined at the smelting works in England, and was accordingly declared by the exporters as British tin.

EXPORTS OF UNWROUGHT TIN FROM THE UNITED KINGDOM IN THE YEARS 1904 TO 1906.

Countries to which Exported.	QUANTITIES.						VALUE.					
	Month ended 31st December.			Year ended 31st December.			Month ended 31st December.			Year ended 31st December.		
	1904.	1905.	1906.	1904.	1905.	1906.	1904.	1905.	1906.	1904.	1905.	1906.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	£	£	£	£	£	£
To Russia - - - - - - -	56	78	153	1,302	1,400	1,126	7,468	11,986	29,582	164,241	194,683	203,829
„ Sweden - - - - - -	29	34	30	434	401	574	3,899	5,362	5,628	53,777	55,642	100,337
„ Norway - - - - - -	7	3	3	111	119	111	1,054	496	538	14,228	16,497	19,203
„ Germany - - - - - -	21	21	17	258	344	381	2,713	3,327	3,156	32,141	47,927	67,659
„ France - - - - - -	48	66	60	653	758	640	6,197	10,247	11,600	82,995	105,643	112,284
„ Turkey - - - - - -	18	34	14	336	240	243	2,324	5,436	3,093	42,404	34,753	43,547
„ United States of America - -	19	57	185	123	1,288	2,139	2,508	7,203	35,817	15,601	172,005	385,223
„ Canada - - - - - -	29	32	52	302	423	513	3,761	4,874	8,334	38,096	59,279	90,143
„ other Countries - - - -	175	217	191	2,345	2,647	2,768	23,721	32,937	38,350	298,364	371,351	486,178
Total - - -	402	542	705	5,846	7,623	8,495	53,645	81,888	136,098	741,847	1,057,780	1,508,403

UNITED KINGDOM IMPORTS OF TIN ORES, 1906.*

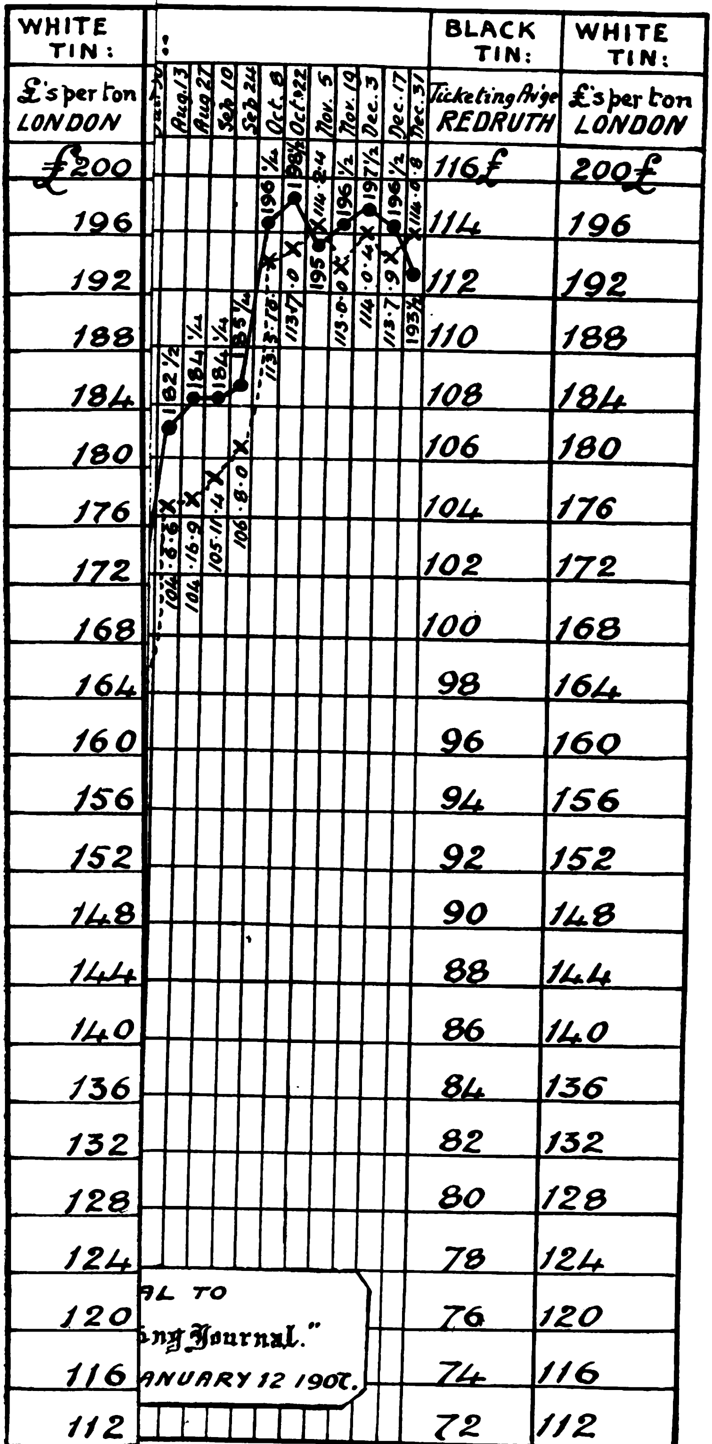
—	To November.	December.	Total for 12 months.
	Tons.	Tons.	Tons.
Russia - - - - -	36	—	36
Sweden - - - - -	3	—	3
Germany - - - - -	567	26	593
Netherlands - - -	249	2	251
Belgium - - - - -	106	2	108
France - - - - -	544	78	622
Portugal - - - - -	56	1	57
Spain - - - - -	168	27	195
Italy - - - - -	32	3	35
Bolivia:			
Peru - - - - -	268	—	268
Chili - - - - -	16,309	976	17,285
Argentine - - -	63	11	74
U.S.A. - - - - -	—	9	9
Canada - - - - -	6	—	6
Cape Good Hope - -	121	12	133
Natal - - - - -	11	—	11
Portuguese East Africa -	304	13	319
Burmah - - - - -	1	—	1
Bengal - - - - -	2	—	2
Straits Settlements - -	86	—	86
New South Wales - -	524	76	600
Victoria - - - - -	10	—	10
Western Australia - -	2	—	2
Total - - -	19,478	1,236	20,714

* Specially compiled for *The Mining Journal*.

MARKET PRICE OF TIN.*

Year.	Highest.	Lowest.	Total visible Supply, January 1.	Year.	Highest.	Lowest.	Total visible Supply, January 1.
	£	£	Tons.		£	£	Tons.
1850 -	85	70	—	1879 -	96	59	18,269
1851 -	88	78	—	1880 -	101	68	21,954
1852 -	98	77	—	1881 -	110	86	20,385
1853 -	125	97	—	1882 -	114	92	16,475
1854 -	126	105	—	1883 -	99	83	15,574
1855 -	130	104	—	1884 -	87	73	16,334
1856 -	143	126	—	1885 -	97	74	13,138
1857 -	150	95	4,118	1886 -	103	92	13,710
1858 -	125	100	5,474	1887 -	167	100	12,239
1859 -	142	125	4,690	1888 -	170†	75	18,226
1860 -	135	129	5,841	1889 -	100	88	14,802
1861 -	130	110	5,781	1890 -	104	88	13,693
1862 -	119	110	6,747	1891 -	94	89	13,050
1863 -	128	113	7,002	1892 -	103	88	12,435
1864 -	120	87	7,184	1893 -	95	74	14,606
1865 -	97	87	9,273	1894 -	74	61	14,316
1866 -	95	75	10,418	1895 -	69	59	27,787
1867 -	91	83	10,856	1896 -	61¾	56	33,073
1868 -	109	87	9,115	1897 -	63½	58½	32,104
1869 -	140	108	7,834	1898 -	86¾	63	29,616
1870 -	135	103	8,797	1899 -	149½	92	22 511
1871 -	157	123	7,742	1900 -	152	108	17,543
1872 -	160	130	6,151	1901 -	132	101	17,131
1873 -	148	114	6,846	1902 -	137	100	18,776
1874 -	121	87	8,289	1903 -	140½	111½	16,151
1875 -	96	76	10,704	1904 -	136½	116⅝	13,948
1876 -	81	70	13,776	1905 -	166¼	129¾	15,398
1877 -	76	64	14,430	1906 -	215	161	13,606
1878 -	66	52½‡	15,596				

* Mining Journal, London. † Highest. ‡ Lowest.


WHITE TIN:
£'s per ton LONDON
BLACK TIN:
Ticketing Av'ge REDRUTH
WHITE TIN:
£'s per ton LONDON
Aug.13
Aug.27
Sep.10
Sep.24
Oct.8
Oct.22
Nov.5
Nov.19
Dec.3
Dec.17
Dec.31
£200
196
192
188
184
180
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72
200£
182½
184¼
184¼
185¼
196¼
198¾
195
196½
197½
196½
193¾
104·6·3
104·16·9
105·11·4
106·8·0
113·3·10
113·17·0
114·2·4
113·0·0
114·0·4
113·7·9
114·0·8
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ANUARY 12 1907.

CHAPTER XXI.

TIN SMELTING.

In this account of tin smelting, only the methods at present employed are described. Strange as it may appear, a considerable quantity of metallic tin is still produced annually by the Chinese using their primitive methods of smelting, of which a short description is given. Otherwise by far the greater part of tin produced is still smelted in the ordinary reverberatory furnace. Tin smelting has been successfully carried on by means of blast furnaces, but the loss of tin is greater, and this is the main consideration in treating a product worth over £190 per ton; also it is well to remember the axiom of Dr. Percy, 'The end of all metallurgical operations is the balance sheet.' Trials have been made with gas furnaces without any marked success, but undoubtedly there still exists room for improvements in tin smelting, certainly one of the oldest and perhaps the most backward of present metallurgical processes.

Tin Smelting in Cornwall.

The ordinary type of reverberatory furnace is in general use in Cornwall. The dimensions of these furnaces are as follows:—Bed 18 feet long, 10 feet to 12 feet wide, fire-bridge 6 feet long by 2 feet wide, 3 feet deep. The bed is made over a hollow arch, and this together with fire-bridge, which is also hollow, is kept cool by a free circulation of air.

The bed is carried on iron bars laid transversely upon these slabs of slate, or fire-clay tiles are laid, which are again covered by a bed of fire-clay, upon which again the true bed of the furnace is built, which consists of first-class fire-bricks laid on end and well grouted in.

This bed lasts about three months and takes two days to renew.

On the ground level below the true bed is a floor of fire-bricks which catch any tin which may have leaked through; this floor slopes towards an iron pan into which the tin is ladled. The bed itself slopes all round to the tap-hole, in front of which is a cast-iron float, near which is a refining kettle with a small independent fireplace; opposite the tap-hole is the charging door, and near the flue is the working door of the furnace, which has an iron roller to help in the use of the rakes, rabbles, etc. Opposite to this working door the fire door is placed high up; this is kept practically closed by the coal when the furnace is in operation, the fireplace being kept full almost to the level of the fire bridge. Such furnace has a stack about 50 to 60 feet high fitted with a damper. A furnace of this description can be built in Cornwall for about £250; this estimate would include the stack and flues.

In building furnaces in Cornwall the work is done by the furnace men. One man can build a furnace bed in two days, and a furnace can be turned out and rebuilt in a week, it taking six hours to charge and run it down to metal, each set of men smelting two charges of ore.

The charge consists of tin ore mixed with very fine culm from 15 to 20 per cent. according to the nature of ore treated. To this is added a little slacked lime and small quantities of slag.

All these constituents are mixed very thoroughly and damped with water. The charge is then placed in position in front of charging door, when it is shovelled in and spread smoothly over the bed by means of a rabble.

The doors are closed or well luted and the fire then put on.

The charge is well melted in about three hours, it is then rabbled and allowed to settle so as to get the slag separated from the metal; this operation is repeated when necessary, and the slag drawn through the working door; if too thin it is thickened by a few shovelsfull of culm; the top layer of slag is generally fairly clean.

The next lot of slag contains tin as prills, and is then crushed and washed, the old beds of furnaces being treated in same manner.

The tapping of a furnace is as follows:—When the charge of ore is seen to be properly smelted, which is indicated by its complete liquidity and the cessation of its working, i.e., giving off its combined oxygen, the process of tapping the furnace is undertaken. The clay stopping of the tap-hole is pierced by an iron bar, and the metal and fluid slag are allowed to run out into the clay-lined basin called the float. The slag quickly cools and sets on the surface of the still liquid metal, and is as soon as convenient removed for further treatment in a slag furnace, and the liquid tin is then ladled into moulds, the flat slabs of tin so produced, weighing about 80 lb. and known as tappings are then ready for refining. On the completion of the tapping process there is still left on the bed of the furnace a considerable quantity of partially consumed anthracite, which holds back a part of the slag and a certain quantity of metallic tin; this mixture of anthracite, slag, and tin is raked out through the working door, and there is generally sufficient slag present to bind the whole into a solid mass which is ultimately taken to a crusher or stamps; the anthracite is removed by a dressing process of stripping or buddling, and the slag and metal are separated by jigging, the slag going to the slag furnace, and the metal, which is generally of a hard character owing to the iron present, goes to a smelting furnace for treatment by itself.

All Cornish ores, having gone through a process of fine stamping, dressing and calcination, come to the smelting house with but little silica or alumina, but invariably with a percentage of oxide of iron and such other heavy metallic oxides as have not been removed in the dressing process. In the Straits iron is added to clean the slags, which appear always to have an excess of silica. At Mount Bischoff the alluvial ores containing an excess of silica are advantageously smelted with ores containing an excess of iron, but in Cornwall all the ores have invariably iron in excess, and in consequence the Cornish smelter has

throughout his operations to contend with compounds of tin and iron, known as hardhead. The usual methods of dealing with this alloy is a calcination to effect an oxidation of the iron, followed by a smelting process having for its object the slagging off of the iron and the reduction of the tin. The process is a tedious one and undoubtedly a good deal of tin is lost in the process.

In Cornwall two-ton furnaces have been adopted, and these can be worked with four charges in the twenty-four hours.

The total number of men employed in the largest smelting works was only sixteen hands for night and day work.

The men are not paid by the hour. There are two shifts of twelve hours, from six in the morning to six in the evening, and from six at night to six in the morning; during the night when four furnaces were at work with two charges in each, the labour of wheeling the charges to the floors, tapping the furnaces, ladling out the metal, removing the slags and everything else rested in five men.

Methods of Buying and Selling Tin Ores in Cornwall.

The cwt. of 115 lb. is adopted. The drafted allowance is not a deduction from the weight of tin ore, but an allowance for the weight of the sacks in which the tin ore is packed. There is no deduction or allowance for moisture; the ores are samples, assayed and sold with their contained moisture. It would be better if the cwt. of 112 lb. were adopted and the ores were sold by dry weight, but the ores are sold by public tender at a price ruled by the market value of metallic tin.

There is no reliable published information as to Cornish smelters' profits or to the loss in smelting, but as regards this last point it is probable that with the best ores the loss in Cornwall is not appreciably different to that experienced in the Straits, and that with poorer ores, with a large excess of oxide of iron, the loss is somewhat heavy. To summarize, the position in Cornwall, which is only satisfactory to the smelter, and with the present revival in Cornish mining, it is to be hoped that the sale of tin ore will be put on a modern footing, that a cwt. of tin ore will be 112 lb. and that a satisfactory arrangement will be come to as to allowance for bags and moisture. This in the writer's opinion would be better in the interest of both the smelter and producer.

The Mount Bischoff Company (Tasmania),

Has erected smelting works at Launceston, the nearest large town to the mine to which the ore is shipped from the mine from Lun Bay; these works also do the smelting for all the rest of the mines in Tasmania at a uniform charge of £3 per ton. Mr. George J. Latta, the smelting works manager, has published in the Report of the Secretary of Mines for Tasmania the following particulars:—

"From a smelter's point of view these ores are as a rule remarkably pure, there being no impurities in them to prevent the metal being

refined up to market quality. The impurity in the Mount Bischoff ores is principally iron, and that in the alluvial ores is silica, and it is a mutual advantage to smelt both together, the iron in the former combining with the silica in the latter to form slag. When alluvial ores are smelted by themselves it is often necessary to add iron in some form.

"The furnaces used are of the reverberatory type, the draught being supplied by a chimney. A charge is made by mixing 50 cwt. of the various ores with about 10 cwt. of small coal; this is thrown into a hot furnace, and the doors carefully closed to exclude air. The time taken to completely reduce the charge is eight hours, during which time it is subjected to several rabblings or mixings. When properly smelted the metal sinks to the bottom of the furnace, and the slags or impurities float on the top; the metal is then tapped into a float, or brick-lined vessel, and allowed to cool for some time, and the slags are skimmed out and reserved for future treatment; another charge is thrown in and the operation repeated. The metal in the float is ladled into a large kettle, where it is refined by sinking billets of green wood under the surface; the heat of the metal converts the moisture or sap of the wood into steam, and causes the contents of the kettle to be violently agitated; this has the effect of releasing any entangled portions of oxide or dross, which float to the surface and are skimmed off. Samples are taken at various times, and, when sufficiently refined, the metal is ladled into moulds. This metal assays 99·80 per cent.

"The slags from the ore vary in richness, according to the quality of the ores smelted and the working of the furnace. These slags are broken up and mixed with small coal and lime, and again smelted, the metal produced from them being very impure from the large amount of iron present. The iron is got rid of by smelting with the next charge of ore.

"A few parcels of ore contain traces of arsenic and copper, and sometimes lead, antimony, and zinc. These have to be treated separately. When arsenic is present every trace must be got rid of by roasting before smelting, otherwise it causes the metal to be hard, and there are no means of eliminating it once it is alloyed with the tin.

"Metal is sent from the works in the form of ingots, weighing 75 lb.; this is for shipment to England. Smaller ingots are made for consumption in the colonies.

"From the ore sent to the works for smelting for private people or companies a deduction of 2 per cent. is made to cover loss in smelting; that is, for 20 cwt. of ore, at 72 per cent., 14 cwt. of metal, or 70 per cent., would be returned to them. This allowance is for ores of 70 per cent. or over; when the quality falls below that a larger reduction is made, as the loss in smelting increases rapidly as the ores get poorer."

Chinese Method of Tin Smelting.

A very primitive method was to dig a hole in clayey ground about 20 inches deep and 14 inches in diameter.

The blast used was produced by using two vertical hollow logs of wood 6 feet 6 inches high and 8 inches in diameter. There was a wood

piston in such log, the two being worked alternately by a man, a bamboo tube conveying the blast into the furnace. The molten metal was collected at bottom of the hole and recast with small clay moulds.

The Chinese furnaces at present in use in the Malay Peninsula are an improvement on the primitive methods described :—

* The Chinese used two forms of furnace, a draught furnace and a blast-furnace; their construction was similar, consisting of a short cylindrical or slightly conical stack made of clay, kept in place by bamboo poles and hoops; the interior consisted of a crucible between 9 inches and 12 inches in diameter, cylindrical at the bottom for more than a foot, with a conical stack 2 feet to 2 feet 6 inches high, opening outwards to a diameter of about 2 feet or more at the top. There was

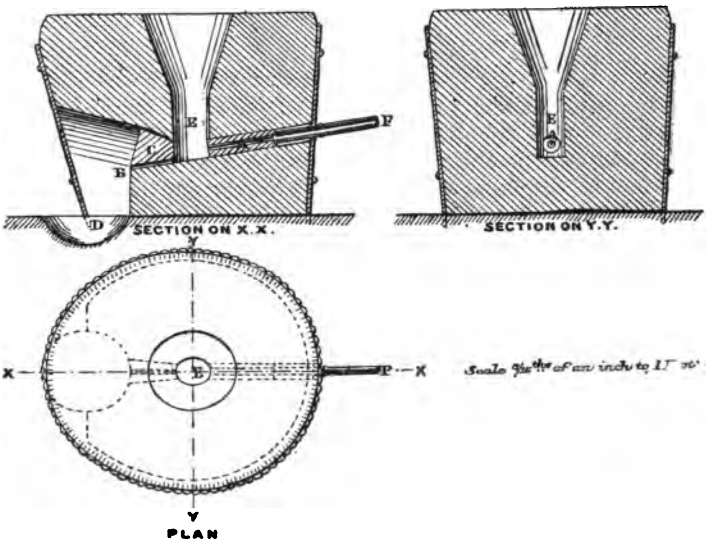


FIG. 38. CHINESE SMELTING FURNACE.

a small tap-hole in front, and an opening at the back that admitted a clay tuyere about 1½ inches inside diameter, or in the other type of furnace admitted a couple of short clay pipes about 3 inches in diameter. The draught furnace was preferred, but could only be used with first-rate charcoal. The furnace, fig. 38, was a mass of clay with bamboo stakes driven into the ground around it, and bamboo hoops to hold it together. The actual furnace, or crucible, was at E; A was a moulded cylindrical clay tuyere between 5 inches and 6 inches in diameter, 2½ inches bore, and about 22 inches long. The bamboo blast-pipe was shown at F, which conducted the blast from what was practically a double-acting blowing cylinder made of a hollow tree-trunk, 12½ inches in diameter and 10 feet long, with a wooden piston

* "Trans. Inst. of Civil Engineers," vol. cxxv.

packed with leaves or feathers. One man mostly did the blowing, more rarely two. The blast was irregular and intermittent, and the average speed probably did not exceed ten strokes per minute. The front of the hearth was arched, and the crucible itself was closed in front, when at work, by a lump of clay, C, through which a small tap-hole, B, about $\frac{3}{4}$ inch in diameter, was kept open by means of a stick, or at times an iron rod. The tin trickled into a hole, D, in the ground lined with clay—the Chinese equivalent of the 'flote.' The molten tin was kept covered with burning charcoal, and from time to time was ladled out and cast into pigs by means of a sand mould, a wooden block being used as a pattern. Each pig weighed 60 kati (80 lb.). The exact consumption of fuel was difficult to ascertain, and varied with the quality of the charcoal within wide limits. Thus about 60 per cent. of tin was obtained from ore that probably contained 68 per cent. or 69 per cent., together with a small amount of very rich slag. This slag was pounded under a rough tilt hammer, washed to extract the prills of metal, and then smelted in small furnaces about 2 feet 6 inches or 3 feet high, these poundings and smeltings being repeated between four and six times before the slag was thrown away as worthless. Now, in watching an operation in one of these furnaces, the top would be found to be comparatively cold; the tap-hole was so cold that even the fusible iron and tin silicate were pasty, and would not run freely, all the heat being in a small reduction zone about the tuyeres. There were three methods of reduction:—(1) Direct reduction of the tin oxide by carbon or perhaps by carbonic-oxide in the region of the tuyeres. (2) There was always some magnetite with the ore, which would be reduced to metallic iron in the furnace just above the tuyeres, and this would in its turn reduce the silicate of tin. (3) It was most probable that the nitrogen of the atmosphere, in the presence of the alkaline carbonates in charcoal-ash, would combine with some carbon to form cyanide of potassium, which, volatilised by the heat of the tuyere zone, would condense somewhat higher up and would reduce the ore at a very low temperature. It was well known that alkaline cyanides were formed under perfectly analogous circumstances in the blast furnace, and the readiness with which such cyanides reduced oxide of tin was equally well known. Probably all three of these reactions came into play in the Chinese method of tin-smelting, and it is improbable that water-gas played any part at all in the reaction.

"Tin-Smelting at Pulo Brani, Singapore." *

To the Straits Trading Company belongs the credit of being the first European company to compete successfully against the Chinese in tin-smelting. In 1885–6, one or two agencies were established in the States of Selangor and Sungei Ujong. It was decided to build works in or near Singapore, on Pulo Brani, an island lying south of Singapore Island and west of the town. It is reached from the business part of

* Extracts from "Trans. Inst. Civil Engineers," vol. cxxv. McKillop & Ellis.

the town by a drive of 3 miles and a ferry of about $\frac{1}{3}$ mile. The island is about 250 acres in extent; and the channels by which ships approach it are fairly easy to an experienced pilot. The chimneys of the works form a conspicuous feature of the view on entering the harbour from the west, and will have been noticed by anyone who has visited the capital of the Straits Settlements in the last eight years. Smelting at these new works was begun in December, 1887, with one 2-ton furnace, and has continued ever since. The works rapidly increased in extent, and at the end of five years practically covered 8 acres. They now consist of twelve 4-ton furnaces with accessory plant.

General Arrangement of the Works.—Everything, with the exception of the European quarters and part of the refinery, is on one level—6 feet to 8 feet above high-water. The ground sloped naturally to the sea-front, and a good deal of cutting and filling has been done at various times to level the place. The high ground at the back, 20 feet to 25 feet above the works level, is reserved for European bungalows. Coal-ships and local steamers lie alongside the wharf, and lighters discharge ore, etc., from the dock direct into the ore-room.

The sheds covering the furnaces, machinery, and coal-sheds have light iron roofs covered with galvanized iron and carried on iron columns. The store and mixing-room is a brick building about 250 feet long by 50 feet wide. The refinery and metal store are similarly built. The bungalows for Europeans are of wood, surrounded with wide verandahs and carried on brick piers. The huts for the coolies are light wooden buildings carried on wooden posts, covered with the thatch of the attap palm—a style of building suitable to the climate and to the habits of the natives. The blacksmiths', carpenters', and other workshops are wooden sheds covered with attap. The superior native servants, mostly clerks and weighmen, have each a brick house, two storeys high, built in the local style with an air-shaft in the centre.

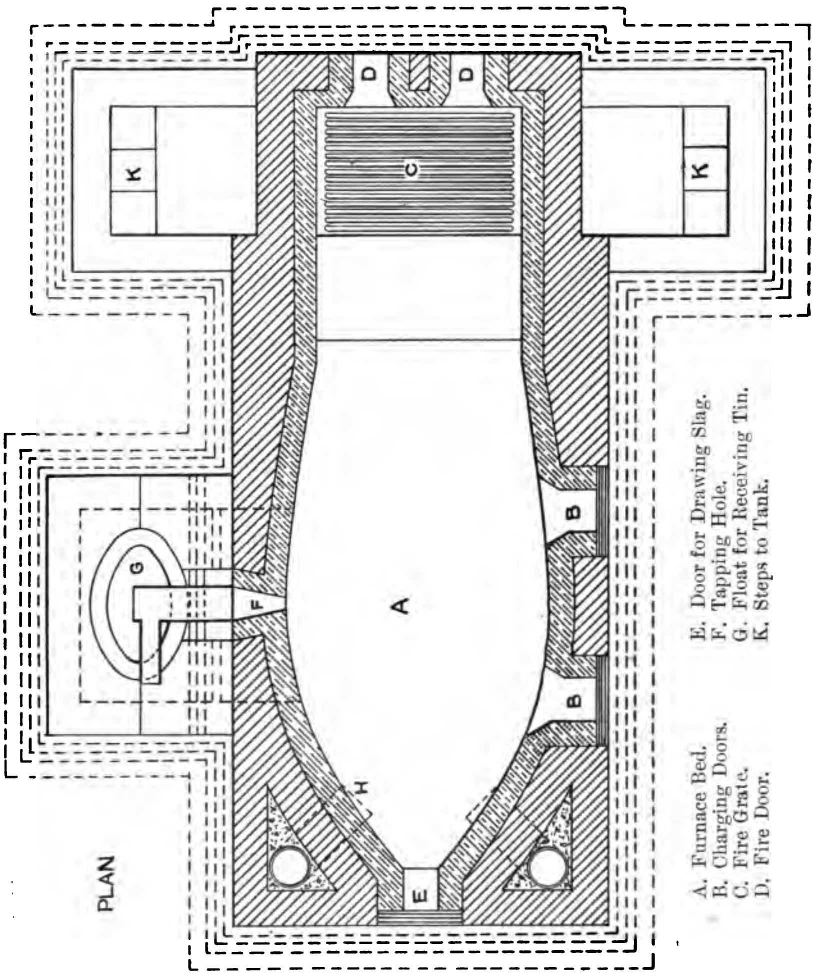
Buying and Handling Ore.—By far the greater quantity of ore landed on the wharf of the works is bought by the Company's officers at various agencies in the native States. Both at the agencies and at the works the value of the ore is determined by cyanide assay. If it contains much impurity, the sample is first boiled in *aqua regia*, and is occasionally vanned. From the appearance and hardness of the assay button obtained, no less than from its weight, the agent fixes the price he will offer. When bought, the ore is sometimes further dressed at the agencies by various devices. The comparatively small quantity to be treated renders any other than manual power impracticable. Hand-jigging and sluicing are the methods usually adopted, yielding ore of high quality and rich tailings. Fortunately natives can be found to work these tailings over again with infinite pains in a "dulang," or wooden dish similar to the Australian miner's dish, but larger and not so deep. The ore is afterwards dried, packed in canvas or jute bags, labelled, and sent down with a guard to the nearest port, where it is shipped direct to Pulo Brani. The ore, when landed, is carried to the store, weighed and stacked under cover by coolies, under the supervision

of a weighing-clerk. The assayer then samples and assays each parcel, and his report determines the subsequent treatment. Those lots which need to be roasted are stored in the roasting-house, while the clean ore is emptied into bins in the mixing-rooms. The cost of the bags is a very serious item. When emptied of ore they are taken to a separate room, cleaned, dried, repaired, packed into bundles of one hundred each, and sent back to the agents.

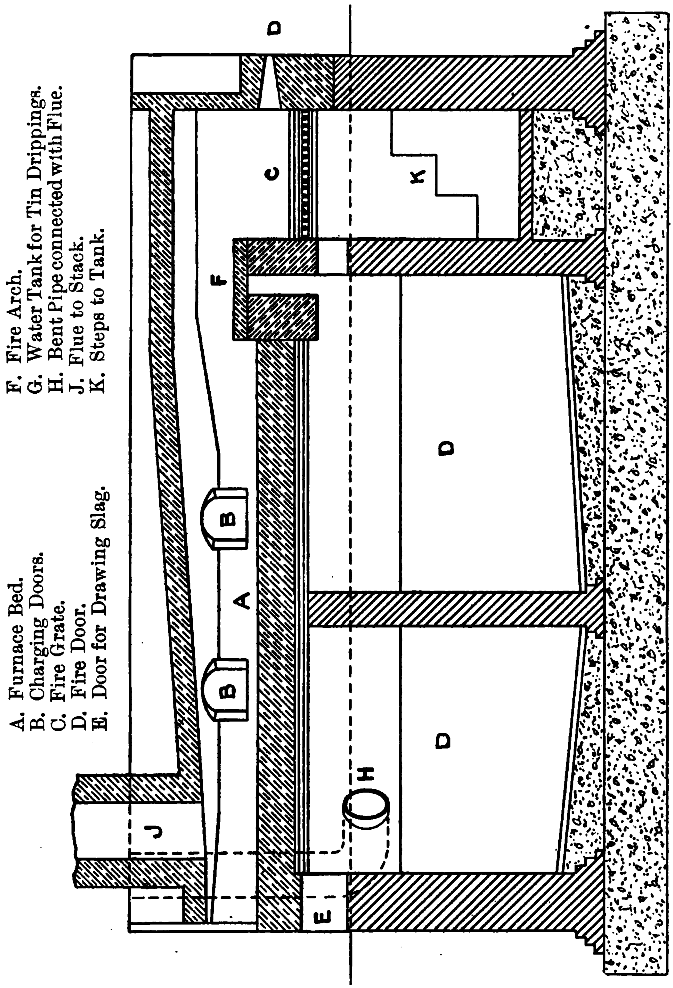
Great care has to be taken in handling the ore. 5·97 cubic feet weigh 1 ton. As it is worth £100 per ton upwards, it can be easily imagined what great loss would accrue from careless handling. Cast-iron floors would undoubtedly be the least wasteful but for the great initial expense. Concrete covered with cement was tried, and did well where there was no wheel traffic ; the barrows, however, broke it up in six months. The best floor tried was made of wooden blocks boiled in tar and arsenic, and laid as close as possible, without other joint than that formed by the excess of tar.

Preparation of Impure Ores.—The production of good marketable tin depends greatly on the quality of the ore smelted. It is true that a great deal can be done to improve bad metal by subsequent refining, but the results are never really satisfactory. The true way to avoid producing tin of inferior quality is to strike at the root of the evil, and eliminate all injurious impurities from the ore before the furnace is charged. The smelter should throw as much of this duty as possible on the miner. At Pulo Brani a sliding scale is used, by means of which the price paid for the ore depends not only on the metallic tin it contains, but also on the nature of the impurities present. The chief of these are mispickel, copper pyrites, and iron pyrites. Wolfram, though never entirely absent, is not present in sufficient quantities to render profitable its extraction as tungstate of soda by the Oxland process. Its chief effect, as also that of the various siliceous and tinaniferous impurities, is to cause loss of tin by increasing the richness of the slags. An incredibly small quantity of arsenic, sulphur, or copper in the ore, is sufficient to render the tin produced from it useless for all purposes except that of manufacturing inferior solder. At Pulo Brani any ore containing arsenic or sulphur is thoroughly roasted at least once. The furnace is of the "blind roaster" type, the ore being in a muffle out of direct contact with the fire. The flame from the fire-box passes first between two arches over the bed and then under it to the flue. During the roasting the ore is rabbled through the charging-doors along the side of the chamber, a suitable flue taking away the gases and fumes evolved. It is found practicable and cheap to roast, when necessary, in an ordinary smelting-furnace, logs of mangrove wood being used as fuel, and plenty of air being allowed to pass through the doors of the fireplace.

When roasted, the ore, unless of very poor quality, in which case it is treated with tailings, is sluiced by Chinese coolies, and gives "good headings," which can be smelted directly ; "coarse tailings," which need to be crushed ; and "fine tailings," which are caught in boxes at the tail of the sluices. The "coarse tailings," after being stamped in a



REVERBERATORY FURNACE EMPLOYED AT PULO BRANI, SINGAPORE.



REVERBERATORY FURNACE EMPLOYED AT PULO BRANI, SINGAPORE.

5-head Californian stamp-battery, are again sluiced. The headings therefrom are re-roasted, and treated on a set of six Frue vanners; while the tailings, together with the fine tailings from the first sluicing, are treated separately, being first somewhat concentrated by passing through a set of fixed buddles, then again roasted and passed over the Frue vanners. Some eight sluices are constantly worked. The stamps are also looked after by Chinese coolies, whilst the buddles and Frue vanners are tended by Kling or Madras coast coolies.

Although this is the general procedure, it is varied greatly according to the nature of the ore. Ore containing copper is allowed to stand for a considerable time between the roastings, to weather as much as possible and to allow the copper sulphate to drain off. Both machine and hand-jigs were largely employed at one time, but the latter proved too expensive to be continued, though they gave excellent results so far as purifying the ore was concerned.

System of Labour in Mixing Charges.—It is usual in tin-smelting works for the charges to be mixed by the furnacemen. This is not a good plan under any circumstances, and it is impracticable where the furnaces are worked by Asiatic coolies. At Pulo Brani all work that can possibly be so arranged is paid by piece. The coolies work under the direction of a contractor, subject to a Chinese clerk to whom the manager delivers his orders in writing, and who is responsible for the weighing and mixing.

The manipulation of the ore is divided into three sections—(1) Discharging from a steamer at the wharf or from a lighter in the dock, weighing, storing, emptying into bins or placing the bags at the roaster, or in the concentrating-shed. This is the work of one gang paid at schedule prices. (2) Mixing; this is the work of a second gang, who have to take the ore and other materials, weigh and mix them, and place the charge in a bin in the charging-room, ticketed to show its destination, at a fixed price per ton. (3) The third stage is the work of a distinct set of coolies, who wheel the charges from the charge-bins to the furnace-door, and leave them ready for the furnacemen to put in. Metal from the furnace to the lighter is treated similarly.

An outline of the detail work of charge-mixing is as follows:—The bins each contain ore of a certain assay value; the day's orders contain directions for mixing the charges by taking so much ore from each bin, in order to keep the assay of a charge constant at a given figure. Welsh anthracite is used as a reducing agent; and drosses, sweepings, skimmings, &c., have to be mixed in ore charges in such ratio as to keep them down in quantity and prevent accumulations.

The Smelting Furnaces.—The furnaces, as shown, at Pulo Brani are of the ordinary reverberatory type. There have been many alterations in them, however, from the pattern originally erected in 1887. The distinguishing feature of the latest furnace is the water vault. Tin at high temperature becomes very fluid; and this property, together with its comparatively high specific gravity, renders it a most difficult matter to prevent leakage. After many trials and attempts to entirely prevent leakage through the bed, all of which failed, it was decided to

regulate the leaks rather than to try to prevent them. The evil of these leaks is not absolute loss of metal, but trouble and difficulty in recovering it. Tin melts at 260° C. The foundations of a furnace, and the ground around it, are at or above this temperature for a distance of some feet. Consequently, any tin that leaks into the vault of an ordinary furnace below the bed remains liquid, and will slowly but continuously find its way through the cracks of the ground until it reaches a place where the temperature is less than 260° C. The distance tin will travel is incredible to those who have not seen it. The cost of the periodical recovery of all this metal is very great; for the metal is either in huge lumps of 10 tons or more, or else in fine strings and sheets into which it has been moulded by cracks in the clay. Sand is said to form an effectual bar to the passage of melted tin. The experience showed that at comparatively low temperatures it does act as a check; but at higher temperatures the tin and sand become mixed so completely that separation by heat is very wasteful owing to the oxidation of the metal. Further, anything siliceous round a tin-furnace should be avoided as far as possible. It will have to be swept up and treated in a furnace sooner or later to extract the tin; and the more silica it contains, the greater will be the quantity of slag produced, and consequently the greater the loss of tin.

This loss of tin by leakage, with attendant difficulties in recovery, have been entirely overcome by the introduction of the water-vault, below the bed, containing a depth of 8 feet of water. Any drops of tin are granulated in this water, and their further passage is effectually checked. Once a week the water is pumped out, and the granulated metal is recovered. In every case, such explosions as have occurred have been due to deficiency of water. If care be taken to rabble down any heaps of granulated metal which form below the water, and if the water-level be maintained, no explosion of a serious nature can occur.

The bed and lining are the most important parts of the furnace, and the most difficult to keep in order. It is necessary to build the furnace in such a way that the bed, lining, and roof can each be repaired or replaced without disturbing the other parts. The bed is of firebricks laid on end. In order to reduce the joints as much as possible, the faces of the bricks are ground true before being laid. They are laid dry, and forced tight with screw-jacks. The rails which carry the bed lie across the furnace, and are divided in the centre. Here they are carried by a strong iron rail, while their other ends rest on the inner $4\frac{1}{2}$ inches of the wall of the furnace. The large rail is carried at each end of the bed on smaller rails built into the brickwork, or by pillars built up from the floor of the vault. Both methods possess advantages. The large rail is divided in the middle, and is there carried by a pillar. The bed is laid with a fall of $3\frac{1}{2}$ inches to the tap-hole from every part of the furnace. This fall is secured by placing the rails accurately in position, the bricks following them. The large rail is first placed accurately along the centre-line of the furnace, with a fall of $1\frac{3}{4}$ inches from the front door and bridge. The $4\frac{1}{2}$-inch work which carries the small rail round the charging-door side is levelled; while that round the tap-hole

side is finished with a fall of 3¼ inches from the bridge and front door to the tap-hole. The cross rails can then be placed in position and the bricks laid. Sometimes the large rail, instead of being divided at the middle, is merely heated and bent. This is very troublesome and has no advantages over the method of dividing the rail. When a bed is worn out, it can be quickly removed by knocking down the centre pillar, when the whole collapses. The courses of bricks in the bed are laid across the furnace, beginning at the bridge. One course is laid at a time, and is carefully keyed up while the screw-jack is on. The bricks are all gauged for each course, $\frac{1}{16}$ inch excess or defect on the width (4½ inches) being rejected. When the bed is complete it is grouted with fire-clay cream, dried carefully and heated. The first charge is cast iron, which, when melted, forms an excellent grout, and binds everything firmly together.

The lining rises from the red brickwork behind the bed. The end brick of each course of the bed abuts on the lining, which must therefore have a true face and the smallest possible joints. The lining is all in headers. Where it meets the roof it is finished off by a course of three-corner end-splayed bricks. The roof, instead of springing from the lining, springs from the outside work of red brick. As this is only 1½ brick thick, the thrust of the roof is taken by T-iron, built in and supported by the vertical girders which bind the furnace. The thrust of the bed of the furnace is taken in the same way by T-iron built into the brickwork. The bridge is built with as much care as the bed. It cannot, however, be kept tight, and is therefore built with a cavity, which is continuous through the outside work. In this way any slag which leaks through and sets can be knocked off with a steel bar. Tin which leaks through the bridge falls into the water in the vault. The doors of the fireplace are in the back wall opposite to the bridge and high up. The fireplace is easily filled through these doors, and the fire-rabble is rarely needed. The coal lies at its proper angle of repose from the roof above the fire-doors down to the bridge, and there are no empty corners possible. Winding is done through a cast-iron winding-plate placed below the fire-doors. The lower row of holes in the plate is about 9 inches above the bars. This form of fire is very easily worked. The "flote," or pot into which the metal runs when the furnace is tapped, is a wrought-iron or steel tank lined on the bottom with 9-inch, and round the sides with 4½-inch firebrick. These leak in spite of all efforts to keep them tight, and the water-vault has been extended under them with good results. In case of any hot material getting through the bed with a rush, two pipes, 18 inches in diameter, are built into the thick corner of the furnace in order that the steam may escape freely.

The working of the furnace is as follows : Suppose a charge has just been drawn. The doors are open and the bed and walls are inspected. If much worn and eaten away they are "fettled." A mixture of bauxite and fireclay moistened with water is put on the worn place with a paddle, and is rammed home with the head of a rabble. When all the bad places are covered, the doors are lowered and the fettling is "glazed" by hard firing for about an hour. This fettling

should be required only once a week, in addition to that given when the furnace is overhauled on Sundays. When the furnace is hot and ready, the doors are opened, the damper is closed, and the charge is thrown on the bed through the side doors, while the leading coolie levels it with a rabble through the front door. The charge being all in, the doors are closed and the fire is made up as large as possible. Meanwhile the charge-wheelers bring out the next charge and tip it under the charging-doors, and one of the four furnace coolies turns it into two heaps, one under each door. The leading coolie then turns his attention to the slag-beds, and prepares them to receive the slag from the charge. As soon as he sees that a fresh fire is needed, he calls the European smelter, who, after inspection through the peep-hole in the front door, decides whether to put on another fire or to rabble the charge. With good coal the first fire should last two hours or longer. This gives the charge a proper start, after which it may be rabbled. It should be liquid near the bridge, and only moderately thick at the tap-hole, where it is deepest, and towards the front door, and frothing freely all over. A good rabbling at this stage should free it from the bed, and mix it thoroughly. The fire is again made up as full as possible, and when it has burned clear the rabble is again used to ensure that everything is loose from the bed. At this time the surface of the charge in the furnace should be resplendent and free from floating lumps and patches. If so, the door is closed, another fire is put on, and the tapping-bar is withdrawn. A stream of tin $\frac{3}{4}$ inch in diameter escapes and falls into the flote. At this rate it requires about forty minutes for all the tin to drain out, leaving only liquid slag in the furnace. When it has been ascertained that all the tin is out, the tapping-bar is again inserted, and the channel from the tap-hole is altered to deliver over the slag-beds. The whole of the clay stopping of the tap-hole is removed, and the slag, rushing out, fills the slag-beds. The tap-hole is then closed, and the furnace is recharged.

Metallurgical Processes.—The metallurgical processes employed may be conveniently considered in four parts.

(A) Smelting ore, with the production of "rich" slag and "ore metal"; (B) Smelting rich slag, with the production of "poor" slag and "rough metal"; (C) Treatment of poor slag containing tin as prill; and (D) Refining the metallic products of (A), (B), and (C).

(A) A charge is made up by mixing ore with between 13 per cent. and 15 per cent. of culm or anthracite, and about 3 per cent. of refinery dross. If the quantity smelted at one time is 4 tons, the composition of the charge would be somewhat as under :—

—	Poor Ores, 65 per Cent. and upwards.	Rich Ores, 71 per Cent. and over.
	Cwt.	Cwt.
Ore	80·0	80·0
Culm	10·4	12·0
Dross	2·4	2·4

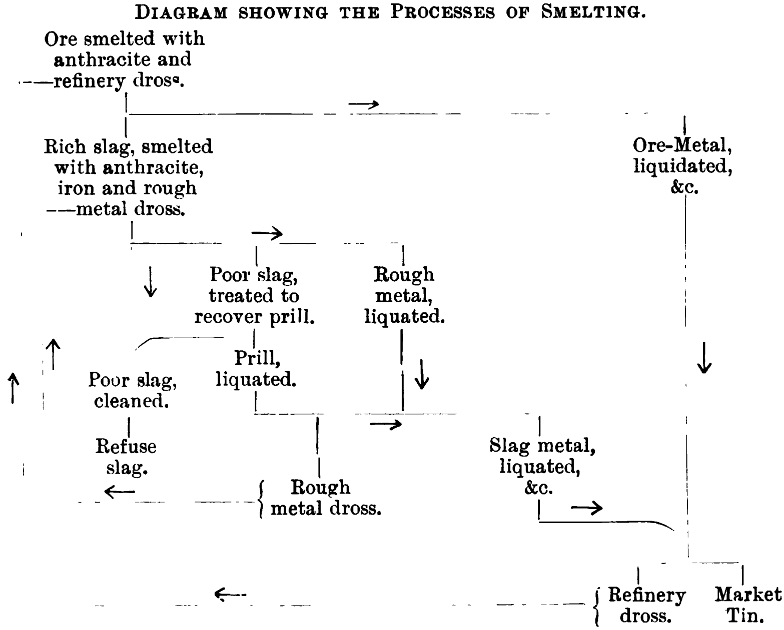
The time required for a charge should be seven hours or eight hours with good coal and labour, but sometimes longer periods are required. From a charge of such composition there should be obtained 45 cwt. to 48 cwt. of metal containing about 99·5 per cent. of tin, and 29 cwt. to 30 cwt. of rich slag containing 30 per cent. to 40 per cent. of tin.

The metal from these charges is hard, brittle, and dull in colour ; it is rather greyer than refined tin, and if poured hot, it may be covered with beautiful iridescent films of oxide.

The slags produced at this stage, distinguished as "rich slags," are variable in appearance—sometimes dark brown and highly crystalline, and sometimes quite black and glassy. In thin sections they show under the microscope a yellow matrix with numerous black crystallites. Reflected light shows tin prills, and at times a brown substance, probably ore that has only been fused. Their composition varies widely. Specimens examined contained 35 per cent. of tin, 15 per cent. of silicon, 18 per cent. of aluminium, and 9 per cent. of iron, in addition to manganese, titanium, lime, and magnesia.

(B) There are many ways of smelting rich slag. They may be tabulated as follows :—(1) smelting rich slag with excess of scrap-iron and culm to produce "hardhead" and poor slag unfit for further use. This method alone is not desirable, as the hardhead produced (an alloy of iron and tin very difficult to separate) is difficult to treat further. (2) Smelting rich slag with culm and sufficient iron to decompose the tin silicate. The difficulty with this method is the danger that the slag produced should be too rich to throw away ; but the metal (termed

DIAGRAM SHOWING THE PROCESSES OF SMELTING.



"rough metal") is fairly soft and not difficult to refine. (3) A combination of the first two methods, by which hardhead is first produced by excess of iron, and is subsequently smelted with more rich slag; the result being that the rough metal is fairly easy to refine, and the slags are sufficiently poor to be rejected. The process, however, requires great care, both in mixing and smelting.

In refining the metal from slag, whatever process is employed, a heavy black dross always remains, containing iron oxide and tin oxide. This is called "rough metal dross," and has to be worked up continuously. The two following methods of working slag are therefore also used :—(4) Rich slag is smelted with culm and rough metal dross, producing rough metal and poor slag—a process which also requires great care—or (5) Rough metal dross is used to replace hardhead in process (B) (3). The greatest objection to all these and similar processes is their intermittent nature. Continuous and regular work is most desirable in metallurgical as well as in other industrial processes.

The mixings required for the above processes are respectively as follows :—(1) 1½ ton of rich slag per charge mixed with 20 per cent. to 27 per cent. of iron and 23 per cent. to 26 per cent. of culm, according to the richness of the slag; (2) 1½ ton of rich slag with 16 per cent. to 20 per cent. of iron and 20 per cent. to 25 per cent. of culm, according to the richness of the slag; (3) 1½ ton of rich slag with 62 per cent. to 70 per cent. of hardhead and 24 per cent. to 25 per cent. of culm; (4) 1½ ton of slag with 62 per cent. to 70 per cent. of rough metal dross and 20 per cent. to 24 per cent. of culm. A 1½-ton charge should be smelted in a furnace similar to that described for smelting ore.

In all the foregoing methods of extracting tin from slag, iron is used, and there is difficulty in ensuring that the exact quantity may be used so that pure tin and pure iron silicate may be obtained. The result always is, that to get a silicate of iron approximately free from tin, excess of iron has to be used, which alloys with the tin, giving rise, when the tin is refined, to rough metal dross. Therefore some of the iron added to the rich slag is lost as silicate, and some returns as rough metal dross. If, then, the ratio of these two quantities be found, the slag may be smelted with rough metal dross and iron in such quantity that the amount of rough metal dross obtained from a charge and added to the charge is equal and constant, while the iron added is just equal to that thrown away as silicate.

The quantities are thus found to be :—Slag, 30 cwt.; dross, 6·5 cwt.; iron, 2·75 cwt.; but the slag resulting from this rational composition of the charge was too rich. An addition of rough metal dross led to the disappearance of this trouble, and the proportions adopted were :—Slag, 30 cwt.; dross, 12 cwt.; iron, 2·75 cwt. The excess of rough metal dross can do no harm, as it only circulates unchanged. In addition to these constituents culm has to be added. Slag is ferrous silicate, and a reducing action must take place simultaneously with the replacing action. Coral or lime in any form is also added as a flux to combine with some of the silica present. It is easy to add too much, in which case it combines with the oxide of tin present, and carries it into the slag.

The final composition of the charge would be, therefore, slag, 30 cwt.; dross, 12 cwt.; iron, 2·75 cwt.; culm, 6 cwt.; coral, 2·4 cwt. This method of smelting slags gave satisfaction in every respect. The details of the process are similar to those given under ore smelting. In smelting slag, however, though the furnace and fuel may be the same, a much higher temperature is attained than when ore is smelted, the duty of the fire being less. It is safe to assume that, in ore smelting, the chemical change represented by the equation $SnO_2 + 2C = Sn + 2CO$ takes place to some extent, and this, being an endothermic reaction, may account for the lower temperature of the ore furnace as compared with the slag furnace, other things being constant. Whatever may be the reaction that takes place with slag charges, it is but slightly endothermic compared with the reaction between the ore and carbon.

A slag charge is rabbled three hours after charging, and again an hour later, by which time the charge ought to be well off the bed and the rough metal ready for tapping. The reaction between the slag, iron and culm takes place with considerable violence. When the frothing and bubbling has ceased, the charge is again rabbled, the rough metal is run into the flote, and the slag into moulds. A slag charge should not require longer than between six-and-a-half hours and seven hours.

The products of melting slag are "second," or "poor," slag, and rough metal. The poor slag obtained is hard, black and glassy. In thin sections under the microscope it shows here and there a small amount of yellow matrix; but it seems to consist chiefly of a dark black crystalline body with the crystals closely packed together. It varies greatly in composition, containing 60 per cent. of silica with varying amounts of other bodies that are also found in the rich slags. This slag contains numerous lumps and prills of tin. The lumps are removed by hand-picking after the pigs of slag fall to pieces. The finer prills are recovered as described subsequently, (C). The rough metal is ladled from the flote into moulds and is stirred, while liquid in the moulds, with an iron rod. This stirring is most important, as otherwise the ingots would tend to set in two distinct layers, the lower and larger portion being practically hardhead, an alloy having a high melting-point, while the upper layer would be nearly all tin, holding a little iron in solution. The same result is attained by granulating the metal. In both methods the metal is constrained to set as a uniform alloy, or mixture of two alloys, and is much more capable of economical liquation in the subsequent refining. The metal is black and dirty in appearance; it is very brittle, and the fracture is steel-grey.

(C) The recovery of the prill may be effected in two ways; (1) by crushing and washing it, as is the practice in Cornwall and Tasmania, and (2) by "running" it in a furnace. The first method was tried at Pulo Brani, but was abandoned, owing to the large amount of the metal reduced to slimes, and rendered difficult of recovery. Slag metal, as pointed out above, is very brittle, and hence it easily forms slimes. The second method is more effective and not more expensive. It consists of re-melting the slags and allowing the metal to sink to the bottom of

the liquid charge. It is not necessary to treat all the second slag in this way. By making the first two moulds in the slag-bed deeper than the others, practically all the metal which does not run into the flote can be collected in these moulds ; and the slag in the remaining moulds (more than two-thirds of the total quantity) can be thrown away as clean. This leaves less than one-third of the slag to be treated. In this process no chemical change has to be effected ; a given mass has merely to be melted and then run off ; consequently, the amount of fuel required is not large.

The charge is rabbled two hours, and again three hours, after charging, after which the slag only is run off. About three times in the week, the metal which has collected on the bed is tapped off, by giving the furnace another fire after the slag has been tapped ; the metal produced being run into sand moulds, and broken up to convenient-sized lumps while still red-hot. This is necessary on account of the extreme toughness of the hardhead when cold ; when it is hot there is no trouble in breaking it up. The metal can, however, be treated in the same way as other rough metal, and stirred in the moulds or run into water. A charge would contain, slag, 40 cwt.; culm, 2·5 cwt.; and coral, 2·5 cwt. If the slag is free from combined tin, the coral and culm may be omitted. They are only added to effect a further reduction of any combined tin in the slag. Four hours is a full allowance for treating these charges.

(D) Liquation is the method principally adopted for refining at Pulo Brani ; but "boiling" is sometimes resorted to under special circumstances. The ingots, or granulated metal, are piled in a furnace heated to incipient redness, wood being used as fuel. Metal which has not been stirred in the moulds, or which has not been granulated, when thus treated, would leave behind large lumps of hardhead in place of the powdery rough metal dross. The products obtained from liquating rough metal, if properly conducted, are about 90 per cent. of "slag-metal," containing 99·5 per cent. of tin; and 13 per cent. of rough metal dross, containing about 65 per cent. of tin, and 25·5 per cent. of iron, partly as oxides and partly as alloys. This dross is mixed into the slag charges, as has been shown, and circulates in constant quantity.

The metal from this liquation is of about the same composition as "ore metal," and its further treatment depends on its destination. For ordinary commercial tin, suitable for making tin plates, solder, or for use in galvanizing, it would be mixed with ore metal, and the two finally refined together. Tin required for making foil or for chemical salts must be very pure and free from iron. It is best in making this quality to avoid any mixture of slag metal, but, if this cannot be avoided, the slag metal must be boiled before it is mixed with ore metal, or the mixture must be boiled after the second liquation.

Boiling is usually performed only on such ore and slag metal as has been derived from ores that have needed roasting and dressing. It consists merely in immersing logs of green wood in the molten metal. The tin is kept just above its solidifying point by a small fire under the kettle. The operation lasts for several hours, until the bubbles of

steam from the wood cease to bring scum to the surface of the tin. The wood is then lifted out, and the metal is skimmed, ladled into moulds, and sent to the refinery, the skimmings being added to the slag charges.

The slag metal is then fit to enter the refinery. The operations performed in it are liquation, followed by "tossing," which consists in allowing molten tin to fall from a height into a mass of liquid metal, thereby carrying air into the mass and permitting a certain amount of oxidation. The liquating furnace is a rectangular chamber with a fire at each end ; the smoke leaves by a chimney in the centre of the arch. The ingots are piled on the bed and wood fuel is used. The tin runs continually through the open tap-holes of the refining-furnace into the two kettles which are situated in the pouring-room. In these the metal is allowed to stand for twenty-four hours, after which it is skimmed and poured into moulds. When cool, the ingots are weighed, and are then stored ready for sale in the ingot room, whence they can be readily loaded into boats at the small wharf. The tin is kept liquid in the kettles at a temperature of as nearly as possible 260° C. On standing, nearly all the remaining impurities settle out from the tin to the bottom of the kettles, and for this reason the bottom 12 inches or so of metal remaining in the kettles is sent back to the refinery to be liquated again.

After liquation in the refinery furnace, the ingots of metal leave behind on the bed of the furnace a grey, powdery body. This substance is known as "refinery dross," and is taken to the mixing-room, where it is added to ore charges. One hundred parts of ore metal will give about 96·5 parts of fine metal and 4·5 parts to 5 parts of dross. Refinery dross is a mixture of the oxides of tin and iron with less easily fusible alloys of the two metals. It contains about 65 per cent. of tin and 11·5 per cent. of iron.

Marketable Tin.—Ingots of good tin should on cooling have a clear, bright surface, with a slight depression on the top, and the crystalline appearance of the surface should show a large pattern. The metal should be soft enough to be marked by the finger-nail, should bend easily, and, if partly cut and then bent, the strained surface should have a smooth, silky lustre, appearing rather as if it had been pulled out than either torn or broken. Impure tin will give the "cry" of tin on bending; but, on cutting and bending the brittleness of the fracture will increase with the impurity. The latter is the only test used by the buyers in the Straits Settlements. It is unsatisfactory, as the four corners of an ingot can be cut and bent so as to show four distinct qualities. The best test is to roll out a piece of the metal. Inferior tin will then show cracks along the rolled edges, and, if the rolling is fine enough, pin-holes will appear through the foil.

Loss of Tin.—One hundred parts of ore, containing 70 parts of tin, 56 parts of ore metal are obtained in (A), which is sent to the refinery, and some 36 parts of slag, containing 12 parts to 13 parts of the original 70 parts of tin. As the dross from the refinery is sent back to the ore furnace, it may be considered that in the end the whole 56 parts

will be obtained. In (B) and (C) the loss of tin commences, and depends upon the amount of poor slag produced, and its richness in tin. The latter may be taken on the average at 5 per cent., and, as 36 parts of rich slag produce about 27 parts of poor slag, the amount of tin thrown away as poor slag will be 1·35 parts, or nearly 2 per cent. of the tin started with. The loss by splashing and theft will bring it up to somewhat over 2 per cent. of the total amount of tin brought into the works. Considering the various refining processes (D), it is clear that when once the work is continuous no loss of tin would take place there; for the various drosses, as in the case of the refinery dross, are returned to the smelting-furnaces. This applies also in the case of the prill in the poor slag, which is returned from (C) to (B).

Consumption of Iron.—It will be evident that the iron added to the slag charges, viz., 2·75 parts in 30 of slag, or 9·17 per cent., is thrown away in the poor slag. Rich slag is about 36 per cent. of the ore, or 50 per cent. of the tin contained in the ore; therefore the consumption of iron is 4·7 per cent. of the tin obtained.

Consumption of Culm.—This amounts to about 17 per cent. of the ore smelted. If the action of reducing tin ore were exactly represented by the equation $SnO_2 + 2\ C = 2\ CO + Sn$, the culm required would be 18 per cent. Anthracite landed in Singapore is expensive, and experience has shown that coal of good quality may be used to replace it. It is necessary, however, to use about 10 per cent. more of the latter. Charcoal may be used, but it is very destructive to the furnace, especially to the flue and "verb," or entrance to the flue from the furnace. This is probably due to the potash and soda it contains.

Consumption of Fuel.—The coal used at first was chiefly Australian. Latterly this has been almost entirely replaced by Japanese coal, and still more lately, owing to the rise in price of the latter coal during the war, it has been replaced by coal from Labuan and the Tonkin coalfields. As the wharves at the works allow ships of 3,000 tons to come alongside, the price of freight is not so high as might be expected, and, except during the wool and wheat seasons, freights are low. The varying cost of coal necessitated a large storage capacity at the works. The coal-sheds are capable of holding about 12,000 tons, and even this quantity proved insufficient on one occasion. The consumption estimated on the average of many months' regular work, for all purposes (including boilers, blacksmith, etc.), in smelting ore averaging 68 per cent. net return, is 1·15 ton of coal to 1 ton of ore.

Tin Smelting at Banca.*

Although the need has long been felt for subjecting to chemical checking the metallurgical processes which take place in the smelting of tin at Banca, this has hitherto not been carried out owing to the

* Specially translated for "The Mining Journal" from the "Jaarbeck van het Mijnwezen," by J. Koomans.

lack of the necessary equipment. In the 1872 Year Book of Mining, Part I., there are indeed some figures stated which relate to the quantity of tin obtained from smelting ore and slag, but particulars are wanting regarding the assay of the smelted ore.

In 1905 a quantity in round figures of 14,000 kilogrammes of ore was smelted under chemical control, the object being to ascertain the quantity of tin obtained, the amount lost, and what became of this lost tin. Where the quantities of slags and tailings obtained were sufficient to admit of the ordinary process of dressing, they were further treated separately.

Before all the chemical analyses had been completed the investigation had to be interrupted owing to departure from Banca. The figures already obtained, however, furnish a good view of the operation of the processes, as may appear from the following.

To contribute to a clear comprehension of the figures which will be given, it must first briefly be stated what processes of treatment tin, ore, slag, and intermediate and waste products undergo at Banca. This will complete but not repeat the description already given in the Year Book, which may be consulted.

Short description of Smelting at Banca.

The first smelting still takes place in the "Flanders" furnace, a "gutter furnace with open twyer," described in the Year Book of 1872, Part I.; the furnace has only undergone some slight modifications. Its dimensions are somewhat larger. Formerly 35 to 40 pikuls of tin per night shift were obtained, whilst at present 55 to 60 pikuls of tin can be smelted per night. Further, the ratio between height and section has been somewhat modified in the course of time, the furnaces having grown somewhat broader.

In addition, in 1889 a second vessel was placed next to that beneath the outflow opening of the furnace. In the first vessel the tin has the opportunity to settle, and the pure tin flows over into the second. This tin is of such great purity that it supplies commercial tin direct in the well-known block form.

While previously, in order to obtain the well-known tin blocks the moulds were straightway filled to the edge, this method of casting was abandoned three years ago, as it was found that blow holes formed in each block of tin, which during transport were filled with water, making its way through microscopical crevices. By casting in four layers, the following layer being only cast just when the previous one shows signs of solidifying, and by using extremely hot tin for the topmost layer, blocks are obtained showing no blow holes, or very insignificant ones.

The impure tin (impure chiefly owing to the presence of iron) which settles in the first vessel is cast into blocks when the night smelting is over, to be subjected later to refining. This tin, called residual tin, forms about 7 per cent. of the entire output.

The manner in which the tin slag is prepared for slag is described in the technical section of the 1883 Year Book. When the fluidity of the slag is insufficient, it is sought to make an improvement by adding lime. The tin obtained by melting the slag from the ore smelting is further refined owing to poorer quality.*

During the last two years the slags which were rejected as worthless by the mining "kongsies"† or the slag smelters (under the system of payment in force), have once more been taken in hand for treatment; but this is now done by the Government direct; that is to say, the work is carried out on a daily wage system.

These slags are crushed fine and classified according to size of grain; each sifting product is washed separately, and the heavier material thus separated is smelted in a small round shaft furnace with open twyer 0·9 metres in height, and having not more than 0·3 metres internal diameter. To render the furnace easily accessible for cleaning the shaft rests loose on the floor. A hand blast supplies the necessary air.

Refining.

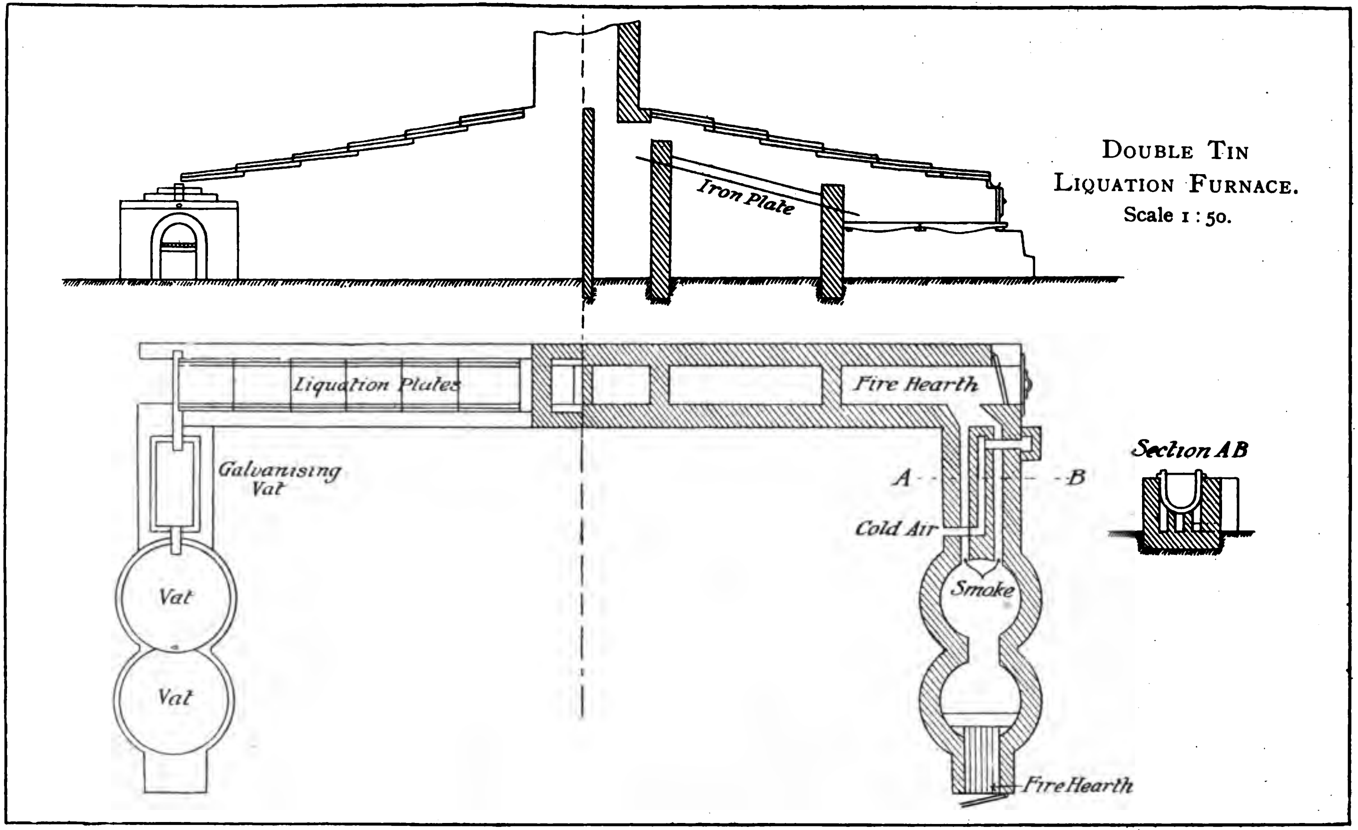
The refining of the residual and slag tin is carried out in a liquation furnace consisting of a series of six cast-iron plates arranged above each other in the manner of roofing tiles, and heated from below. The plates are at slight inclinations of 5 to 9 degs., the lowest being most horizontal, and each higher one at a greater slope.

The refining tin is usually yielded on the second and third plate only, the pure tin flowing off and the impurities remaining behind. The dross left behind is transferred to the fourth plate by means of a shovel. Owing to the removal of the tin by liquation, the remaining mass becomes continually harder; in order to get any more tin to flow out the temperature must be slightly raised. The hearth is therefore arranged in such a way that the plates lying higher up are heated more than the lower. The mass of dross on the fourth plate, when it yields no further appreciable amount of tin, is shifted to the fifth and then to the sixth plate. On these two plates it is only by pressing that any tin can be made to flow out. This exudation is effected by compressing the tin against the raised ribs provided on the edges of the liquation plates. The tin flowing from the liquation plates is, in order to give the accompanying impurities of higher specific gravity than the pure tin an opportunity to settle, conducted into a settling tank, and from this successively into two cast-iron pans placed stepwise beneath each other; it always flows over into the following tank. From the last pan the tin is cast in blocks.

The temperature of the settling pan may not be higher than is

* All tin obtained from poor ore such as gangue ore ("gangerts"), ore obtained by re-washing already used-up soil, alluvial tin ore containing pyrites, etc., are likewise refined.

† Piecework contractors.


DOUBLE TIN
LIQUATION FURNACE.
Scale 1 : 50.
Iron Plate
Liquation Plates
Fire Hearth
Galvanising Vat
Vat
Vat
A
B
Cold Air
Smoke
Fire Hearth
Section AB

necessary to maintain the tin in liquid condition. It can be regulated by allowing a cold current of air to flow in contact with the bottom. The impure tin which then settles at the bottom possesses a higher smelting temperature than pure tin ; this property renders it possible to remove the impurities by means of a perforated ladle, and to purify the tin bath in this way. The impure tin thus removed is once more transferred back to the liquation furnace.

The pan between the settling tank and the casting pan serves for checking purposes only ; from time to time small assay bars are cast in order to examine whether the tin still fulfils all requirements as regards purity.

It occasionally happens that the tin contains impurities which can only be separated by poling, as, for instance, occurred in 1898 in Muntok. Fresh wood is then plunged into the tin bath, and, owing to the gases which develop, a scum forms, which consists for the most part of tin, but in addition embodies the impurities. The scum can easily be taken off with a perforated ladle.

The tailings or waste from the liquation furnace, partly granular and partly pulverulent, are in some measure converted into oxides owing to the high temperature of the plates. They still possess a high tin assay, and are therefore melted in the Flanders furnace. Part of the impurities scorifies, but the greater part is retained in the outflowing tin. This impure tin is once more refined, but a second liquation is necessary in order to obtain entirely pure tin from it.

On the average one liquation furnace with two shifts of eleven men yields 500 blocks weighing 285 pikuls (17 tons) of refined tin every twenty-four hours. Of each shift three men are occupied with the liquation, one man is engaged in stoking, two men in casting, and five men on various work. The consumption of wood fuel (the furnace is heated by wood) amounts to 0·020 cubic metres per pikul of tin refined. The wood used is bakau wood, the price of which in Banca varies between fl. 2 and fl. 2·75 per cubic metre. The wages paid are fl. 0·15 to fl. 0·20, and sundry expenses, lighting, &c., 3·5 to 5 cents per pikul of tin refined.

The total cost of tin refining in Banca varies from 25 to 30 cents per pikul of tin refined.

The drawing appended represents a double liquation furnace ; that is, two liquation furnaces with a common smoke stack. This is the form in which it is usually built in Banca. If in earlier days there was a possibility of isolated blocks of inferior quality being put upon the market, the measures taken during the past few years, as described above, have rendered it impossible for blocks containing any considerable quantity of impurities to be shipped. The average purity of Banca tin has therefore advanced.

Between the tin originating from the first smelting process and refined tin no distinction is made, because a number of chemical analyses have shown that no difference in quality can be found ; both kinds are of great purity.

Results of the Examination.

The assay was always carried out with ore from mine No. 2 Blinjoe, which mine is worked in the upper reaches of the Soengei Boeboes. The ore had a size of grain of 0·2 to 4 millimetres.

	Kilogrammes.
Air-dried ore weighed off - - - - - -	14,579
(The contents of moisture amounted to 0·15 per cent.)	
If deduction be made for this amount of moisture, the weight of the tin ore is found to be - - - -	14,557
With this ore three tin assays were arranged; for each assay a fresh sample was taken on the diagonal method. The average found was 72·97 per cent. of tin. The tin, therefore, contained in the ore is	10,622

The tin value of the valley ore on Banca reached a somewhat higher average.*

The smelting of this mass of ore required three smelting nights. During the first and second nights an approximately equal quantity of ore was smelted, but during the third night about one-sixth less.

As is customary in smelting ores, the slags were once more smelted towards the end of the night.

1st Night.—Began smelting at five o'clock p.m., terminated on the following morning at nine o'clock. Duration of smelting thus sixteen hours. Obtained :—

	Kilogrammes.
87 blocks of shipping tin, weighing - -	3,135·5
and 9 „ of residual tin, weighing - - -	321·2
Total - -	3,456·7

Consumption of charcoal, 208 baskets, one basket containing on the average 24 kilogrammes of charcoal; in all, therefore, 4,992 kilogrammes.

The number of blocks of residual tin were somewhat larger than necessary; the furnace was new, and the first receiving vessel made somewhat too large. By lowering somewhat the outflow opening into the second vessel, the desired number of blocks of residual tin was obtained on the second and third nights.

2nd Night.—The smelting was begun at 3.30 p.m. and ended at 7 a.m.; time, therefore, 15½ hours. Obtained :—

	Kilogrammes.
93 blocks of shipping tin, weighing - -	3,361·3
and 7 „ of residual tin, weighing - -	251·6
Total - -	3,612·6

* See "Year-Book of Mining," 1897, page 182.

The charcoal consumed was likewise 208 baskets, or 4,992 kilogrammes.

3rd Night.—The smelting began at 3 p.m. and completed at 7.30 a.m., thus covering 16½ hours. Obtained :—

		Kilogrammes.
	78 blocks of shipping tin, weighing - -	2,802·8
and	5 „ of residual tin, weighing - - -	180·1
	Total - -	2,982·9

The charcoal consumption was 188 baskets of an average of 24 kilogrammes = 4,512 kilogrammes. Hence the total obtained during the three smelting nights was :—

	258 blocks of tin for shipment, weighing -	9,299·6
and	21 „ of residual tin, weighing - -	743·9
	In all 279 blocks, weighing - - - - - -	10,043·5

forming 68·99 per cent. of the dry ore.

From the tin for shipment an average sample was taken by running off a proof bar before and after every cast of ten blocks, and afterwards sawing these test bars through. The chemical composition of the shipping tin appeared to be :—

Tin - - - - - - -	99·87 per cent.
Iron - - - - - - -	0·13 „

There were not even traces to be found of lead, copper, or silver.

This tin does not represent the average of Banca tin ; in conjunction with the somewhat inferior quality of the ore smelted, the contents of tin are slightly lower than usual. It may, nevertheless, be described as very pure.

The residual tin had the following average composition :—

Tin - - - - - - -	98·82 per cent.
Iron - - - - - - -	1·05 „
Sulphur - - - - - -	0·11 „
Copper - - - - - -	0·01 „
Lead - - - - - - -	0·01 „

In order to determine the average composition, the twenty-one blocks of residual tin were sawn through the centre and a sample taken from the saw filings.

These three smelting nights yielded a total of 2,020 kilogrammes of slag, weighed directly after smelting was completed, and, therefore, still moist with the water with which they had been quenched. This extinguishing of the red-hot slags is for the purpose of making them easy to crush later. After they had been dried they were crushed fine in a Carr's disintegrator and sifted. After these operations they only weighed 1,740 kilogrammes. This loss of weight must be attributed, in the first place, to the drying ; but also in part to the escape, as dust

of charcoal which the slag contained and which was crushed to fine powder by the disintegrator.

The slags were, by sifting and hand selection, divided up into three parts, namely :—

	Kilogrammes.
A.—Fine part, width of mesh ¾ mm.	471
B.—Coarse part, width of mesh 4 mm.	1,249
C.—Sifted pieces of tin and large pieces of tin sorted by hand	20

The tin assay of each of these three lots and, likewise, the charcoal contents of A and B were determined. These figures, calculated for the entire quantity of slags, yielded the following amounts :—

14·5 per cent. of charcoal and
26·3 per cent. of tin.

In lot B some pieces of slag were picked out—which showed no visible tin beads—for closer chemical examination. They were found to contain—

Tin, partly in metallic form and partly present as

SnO_2	16·0 per cent.
CuO	0·4 „
TiO_2	0·7 „
WO_3	0·2 „

Whilst in the residual tin a trace of lead was found, the slag appeared to be free from lead.

The following calculation may serve to ascertain the loss of tin—due to ore smelting :—

		Kilogrammes.
Quantity of tin present in the ore		10,622
Quantity of tin for shipment obtained, multiplied by the assay—*i.e.*, 9299·6 × 99·87 per cent.	9,287·5	
Quantity of residual tin obtained, multiplied by the assay—*i.e.*, 743·9 × 98·82 per cent.	735·1	
Quantity of tin contained in the slags—1770 × 26·3 per cent.	465·5	
		10,488·1
Lost in smelting		133·9

Expressed in percentages, 1·26 per cent. of the tin present in the ore was lost, or 0·90 per cent. of the weight of the ore.

This loss must be attributed—

1. To the finer ore being blown away from the furnace and to evaporation of tin. This could be met by fitting a chamber for catching the volatile dust.

2. Owing to the smelted tin sinking and being lost in the furnace.

Part of the lost tin is reclaimed when the furnace is demolished and the floor of the smelting room broken up and washed. The fine ore blown out of the furnace is—as much of it as settles in proximity—trodden into the clay floor of the smelting house.

It is impossible, owing to the lack of data, to state in figures what is the quantity of tin later reclaimed per smelting night.

Treatment of Slag.

Slags before smelting are first washed in a small trough.

This operation removed from lot A 199 kilogrammes, and from lot B 548 kilogrammes; in all, therefore, 747 kilogrammes, of which 245 kilogrammes must have been charcoal. Hence, there were subjected to one smelting—

	Kilogrammes.
Fine slag up to $\frac{3}{4}$ mm. size of grain	272
Coarse slag up to 4 mm. size of grain	701
Minute fragments of tin	20
Total	993

The smelting took place in a small furnace, entirely similar to the "Flanders" furnace, but only of half its capacity. The smelting lasted from 10 in the morning till 7.30 in the evening; 46 baskets of charcoal weighing 1,100 kilogrammes were used. During the smelting the slags which had once passed through the furnace were once more crushed, washed, and fed in again. In this way a further 390 kilogrammes were washed away.

There were obtained—

	Kilogrammes.
Eight blocks of slag tin, weighing	277·5
Tin residue in the collecting vessel	0·75
Slag	357

This quantity of slag is too small to be further treated alone.

The tin had the following composition:—

Tin	97·83 per cent.
Iron	2·17 „
Copper	trace.
Sulphur	trace.

To obtain an average sample the blocks were again sawn through. The 357 kilogrammes of slag were, in order to obtain an average sample to determine the tin assay, crushed fine in the disintegrator. The tin assay appeared to be 10·56 per cent., of which 4·1 per cent. could be sorted or sifted from the slag in the shape of tin beads. The slag tin contained $278{\cdot}25 \times 97{\cdot}83 = 272{\cdot}2$ klg. of tin. The slag contained $357 \times 10{\cdot}56 = 37{\cdot}7$ klg. of tin.

The slags from the ore smelting contained 465·5 klg. of tin. Thus there were lost 155·6 kilogrammes, which can partly be recovered at the mouth of the trough or sink, and have partly disappeared by evaporation and by air current in the furnaces and elsewhere. It may be assumed that from the 357 kilogrammes of slag which remain from the slag smelting 5 per cent. of tin may still be won by a repetition of this process, making in all 17·8 klg. The 892 klg. of slag washed away were, owing to the smallness of the quantity, not further treated by the method given above.

At Blinjoe a large lot of slag of the same origin as the above had its tin assay determined. This appeared to be on the average 8·1 per cent. From this slag one-fifth of the tin contained was got; that is, 1·6 per cent. of the weight of slag.

It may be assumed that the 892 kilogrammes of slag in question being of the same quality will, on further treatment, yield a like proportion, *i.e.*, 892 kilogrammes × 1·6 per cent. ≐ 14·3 klg.

The 743·9 klg. of residual tin, the 278·3 klg. of slag tin, and the 17·8 and 14·3 klg. of slag tin to be extracted by further treatment of the slag, making in all 1054·3 klg., must be subjected to refining on the method described above; the quantity is, however, too small to be worth separate treatment in the liquation furnace.

It may be taken as an average that in refining in Banca the first liquation yields 94 per cent. of the weight of the tin to be refined in the form of tin ready for shipment, and a further 4 per cent. is yielded by smelting the waste and fresh liquation of the product thus obtained. As to the above-named lot of tin, it may be assumed by analogy that 1033·2 klg. of marketable tin will be yielded.

In 1904, in refining at Djeboes, by casting a test bar before and after each casting, the average composition of the tin refined during the year was investigated.

This appeared to be—

99·92 per cent. of tin, and
0·08 per cent. iron.

No trace even of other impurities could be found. The refined tin is therefore equal in quality to the other marketable tin.

Results.

Apart from the fact that later on, when the smelting house is demolished, some tin will be obtained, we arrived at the result that 14,557 klg. of tin ore with an assay of 72·97 per cent. will yield, upon the method of treatment in use in Banca, 9299·6 kilogrammes + 1033·2 kilogrammes = 10332·8 klg., or 70·98 per cent. of marketable tin with an average assay of 99·88 per cent., and that there will be lost 10622 = (9299·6 × 99·87 per cent. + 1033·2 × 99·92 per cent.) klg. = 302 klg., or 2·07 per cent. of the weight of the tin ore.

Smelting Costs.

Wages and implements in smelting ore in Banca account for a cost of 40 to 45 cents. per pikul of tin smelted, including residual tin. The costs of the charcoal used differs in a great degree. According as the smelting establishment is closer to or farther from the wood where the charcoal is burnt, and as the distance of transport of the charcoal varies, the prices paid for the charcoal differ, and are contracted for with the charcoal burners at fl. 1·05 to fl. 2·20 per pikul of smelted tin.

The costs of crushing and washing the slag, preparing it for smelting, also vary to a fair extent, owing to difference in quality. It may be assumed that as a rule not less than fl. 3 and not more than fl. 6 are expended per pikul of tin smelted. The outlay for the smelting slag per pikul of tin produced is somewhat higher than in smelting ore, because a night of work, the costs of which are the same, yields 20 to 25 per cent. less of tin. Payment for the charcoal consumed is similar to that in ore smelting.

The re-treatment of the slag removed by washing and originating from the first treatment of slag, the cost of washing, smelting and refining, wages, tools, charcoal and wood fuel all included, amount to fl. 27 to fl. 30 per pikul of tin produced.

The refining of residual and slag tin, as far as the first liquation is concerned, costs per pikul of tin 25 to 30 cents. in wages, wood for fuel, and sundries, as already stated. The marketable tin obtained from the liquation tailings costs fl. 4 to fl. 5 per pikul for refining.

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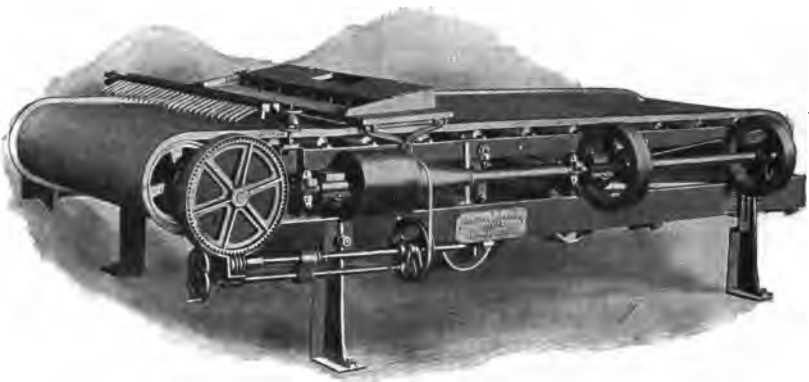

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